ENGINEERING:

An Illustrated Weekly Journal.

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ON REDUCTION GEARS.

By JOHN H. MACALPINE.

Introduction.—The writing at this time of what follows was suggested by a careful study of a paper on "Geared Turbines for Ship Propulsion," read before the Institution of Engineers and Shipbuilders in Scotland on October 27, 1914. In the names of the authors, Messrs. W. D. McLaren and G. M. Welsh, I think I recognise two friends who were together with me in Messrs. Robert Napier and Sons, Glasgow, under that distinguished engineer, Dr. Alex. C. Kirk, one whose friendship, extending over many years, I will always gratefully remember.

Messrs. McLaren and Welsh's paper, a short notice of which appeared in ENGINEERING, vol. xcviii., pages, 538, 539, is a most careful and detailed discussion of the powers, weights of machinery, economy, &c., of twelve typical ships, comparing the results for a geared-turbine installation with that for reciprocating engines, direct connected turbines, or a combination of the two. The paper well repays close study. This estimate is in no way modified by my remarks being slightly critical of a few of the many points with which the authors deal.

The questions I will discuss arise almost altogether from the section "Gearing." While Messrs. McLaren and Welsh's paper will usually be easily accessible, I will, for convenience of the reader, make what I say complete in itself.

The authors use an involute tooth with a circumferential pitch of 0.7854 in. in *all* gears, the pinions in the examples they tabulate ranging from 4 in. to 12 in. in diameter. As they state, "Very little experience has yet accumulated to enable a decision to be arrived at for selecting the maximum permissible load between the wheel teeth." They assume a load of 370 lb. per inch for this pitch of tooth on a pinion of 6 in. diameter, and set down a curve from which the loads per inch of tooth for all other diameters of pinion can be found. The form of the curve seems to be arbitrarily chosen, but the intensity of pressure rises with the increase of diameter. The reason for allowing an increase is that the teeth "have a curvature of face dependent on the diameter of the base circle, and hence the teeth on a small pinion offer a less extensive bearing surface than those on a large pinion." To this it might have been added that a larger arc of contact can be used with a larger pinion. Both causes justify the assumption of some rise of pressure per inch as the pinion diameter increases.

The principles which have guided them further in proportioning the gear are not obvious. The revolutions per minute are first determined for the turbine from considerations of peripheral speed, &c., which I need not detail. This leads to curves of turbine and pinion revolutions per minute, the abscissa being shaft horse-power. The revolutions per minute are fixed at 3000 for the high-pressure turbine up to 2700 shaft horse-power, and for the low-pressure up to 1400 shaft horse-power. For higher powers the revolutions per minute falls, that for the low-pressure being lower than that for the high-pressure.

Curves of pinion diameter are then laid down on a base of shaft horse-power. That for the high-pressure pinion is a straight line rising from 4-in. in diameter for 500 shaft horse-power to 10 in. in diameter for 7000 shaft horse-power transmitted by the gear, half passing through the high-pressure and half through the low-pressure pinion. Above 2700 shaft horse-power the pitch-line speed of this pinion is nearly constant—in the neighbourhood of 4800 ft. per minute; but why this should be so is not stated. The curve of diameter of the low-pressure pinion is made up of broken lines consisting of three straight parts. Up to 1500 shaft horse-power it coincides with that for the high-pressure pinion; it then rises more rapidly till 2700 shaft horse-power; afterwards the rise is less rapid than in this middle portion, though more rapid than that for the high-pressure pinion.

On the proportioning of the pinion diameter the authors state: "It is not essential that this diameter should be a linear function of the power, and perhaps it could with as much reason be made a linear function of $\frac{\text{power}}{\text{turbine revolutions}}$. This matter is unimportant for the present purpose, as it principally affects constructional details." I shall show that the question is of the most fundamental importance, that the curve of pinion diameter can be laid down *only* on an abscissa of $\frac{\text{power}}{\text{revolutions}}$ if the highest results are to be attained, and that the curve is far from being a straight line.

Having fixed on the load per inch of tooth, and the diameter and revolutions per minute of pinion, the authors then calculate the width of gear necessary to transmit the required shaft horse-power. This leads to a ratio of width of gear to diameter of pinion ranging from 2.5 to 6.95. (I omit one example, where, for specified reasons, the pinion diameter is increased and its length diminished from the values given by the curves.) For the very wide gears the authors suggest that it would be well to divide the gear into two, one forward and one aft of the turbines, thus narrowing the face; and they propose an arrangement which seems excellent for very high powers, but not necessary for the powers being transmitted by each pinion in the three cases for which they suggest this division. In their reasons for avoiding these very wide gears, and indeed in their whole paper, the authors do not refer directly to the transverse deflection of the pinion, though this and the torsional yield are by far the principal factors in determining the allowable width in proportion to diameter, as I shall show. Especially in pinions with two bearings the cross-bending is of high importance.

To return to the pitch of the teeth: The chosen pitch of 0.7854 in. gives sixteen teeth for the smallest pinion tabulated—viz., 4 in. in diameter. With any usual values of obliquity of action of the teeth and ratio of addendum to pitch, this small number of teeth would produce interference.* The largest pinion tabulated, 12 in. in diameter, would have forty-eight teeth. I will endeavour to show that the best results can be attained with a constant number of teeth in the pinion, not with a constant pitch.

As none of the fundamental questions involved in the design of reduction gears was raised in the discussion, it is possibly fair to assume that in a large proportion of cases designers have not clearly appreciated their application, though the principles themselves are universally known and appreciated. This suggested to me that it might be well to discuss the question afresh, as it is a problem to which I have given prolonged consideration; and it is my excuse for criticisms, which are made in the most friendly spirit. I will discuss the various actions and errors which affect the distribution of stress along the teeth and the proper action of the gear; how we were forced to adopt the floating frame to attain the best possible results; how theory points to the beneficial action of the floating frame in greatly diminishing the most important difficulties; and, next, I will give data showing that experience has fully vindicated the leading of theory. I will then proceed to give the interpretation of what I have called the "power constant" and discuss various questions regarding the design of teeth. Finally, the marine installations given by Messrs. McLaren and Welsh will be re-discussed, showing in several cases the additional saving, in weight and steam economy, which can be effected by the rise of the power constant made possible by the use of the floating frame.

I regret that the late date at which I was able to study Messrs. McLaren and Welsh's paper rendered it impossible for me to bring my comments before the Institution of Engineers and Shipbuilders in Scotland during the period when the discussion was in progress, and hence I am dealing with the matter now. I hope to show that consideration based on elementary principles leads to a simplification of the problem; and the reduction in the number of variables will make it easier to deduce from experience correct values of the constants involved.

Preliminary Propositions.—In reduction gears for transmitting the power of turbines, any change which would allow the machine to be made smaller or lighter without diminishing the factors of safety, the load and speeds of pinion and gear remaining the same, would be considered an improvement. Any power, however large, can be transmitted if the reduction gear is made large enough; but if too large and heavy it cannot be applied, for instance, to the propulsion of ships. This is one most important criterion in judging reduction gears.

Let us take any design of reduction gear and suppose that some change is made in its proportions. This will either be advantageous or the reverse; it will either allow a greater power to be transmitted safely at a given speed or it will diminish the safe load. For instance, if the pinion is very short in proportion to its diameter, an increase of length will allow a higher power to be transmitted. On the other hand, if the pinion is already too long, deflecting in the centre so that the teeth there bear little or no load, and yielding too much torsionally, a further increase of length will only further concentrate the stress on a portion of the teeth and the safe load will be diminished. Or a change in the number and pitch of the teeth might be supposed. It requires little reflection to perceive that the tooth pitch may be too fine or too coarse.

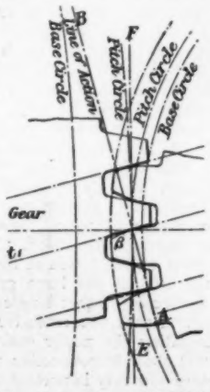
Thus:

Proposition A.—In any type of design of reduction gear, with a given diameter of gear and pinion, there is one set of proportions which is better than any other.

I will now prove a proposition regarding similar machines, which must be so well known that I apologise for doing more than referring to it. But it is at the base of the whole question. Fig. 1, page 416, shows portions of any two similar machines, A and *a*, in corresponding configurations. Any portions of any machines might be used in the figure, but I have chosen rods B, *b*, acting on levers C, *c*, by surface contact, as in the case of teeth, and the levers mounted on shafts D, *d*. The rods are under axial compressive forces F, *f*, which apply a complex internal system of stresses to the levers. These are partly made up of tension, partly of shear, and partly of cross-bending. The shafts are under torsion, and also some cross-bending, the amount of which depends on how they are supported. I will not take account of gravity or friction, which, in the case of gears, are relatively unimportant. Then obviously the systems of external forces applied to each part must be similar, as they may be deduced geometrically from the same diagram

Let the linear dimensions of A and *a* be in the

* As is well known, in gearing with involute teeth the line of action, or contact, is a straight-line tangent to the base circles of the gear and pinion, A B, in the annexed diagram, and the angle of obliquity is the angle this line makes with the normal to the line of centres, E β F. From the mode of description of the tooth, the radius of curvature at any point of contact is the distance from this point of contact to the point of tangency of the line of contacts with the base circle, of the pinion for a pinion-tooth, or of the gear for a gear-tooth. (Thus,



A β is the radius of curvature of the pinion-tooth at the point β on the pitch line.) Hence, at this point of tangency the radius of curvature is zero. This evidently forms a limit of depth beyond which a true involute tooth cannot be cut, and in a well-designed gear it is not too closely approached. The above point of tangency of the pinion should therefore lie outside the addendum circle of the gear. If it does not, there is said to be interference, and the continuation of the tooth form within the base circle is necessarily incorrect. The difficulty does not usually occur with the large gear.

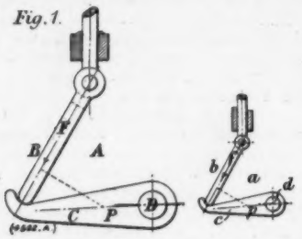
proportion N : n, and for the applied forces F, f, let

$$F : f :: N^2 : n^2.$$

As the force sy tems are similar, it follows that at all corresponding sections the total tensional, compressive, or shearing stresses, are in the proportion $N^2 : n^2$ But the areas of the cross-sections which have to withstand these forces are in the same proportion. Hence the stress per square inch due to tension, compression, or shear, is the same at corresponding points.

Again, the moments producing cross-bending at any corresponding points, P and p, or torsion in the shafts, D and d, are in proportion to the forces multiplied by the linear dimensions—that is, as

Fig. 1.



$N^3 : n^3$. But the moments of resistance of similar sections per unit fibre stress are also proportional to the cubes of the linear dimensions. Hence the stress per square inch due to cross-bending and torsion is the same at corresponding points.

If the materials of which the machines are made have the same moduli of elasticity at corresponding points, the rate of distortion, or the yield per unit length, whether extension, compression, or shear, will be the same, as the stress systems are the same and of the same intensity. Hence the total distortion of the machines will be proportional to the linear dimensions and the configurations of A and a will remain similar even after F and f are applied. It is obvious that if this is true at all internal points, it is true also at the contact surfaces where forces external to each part are applied; for, if true for internal points, it must be true for those only infinitesimally removed from these surfaces.

To state the proposition generally:

Proposition B.—In any similar machines with similarly-applied loads in proportion to the squares of the linear dimensions, and in similar configurations:

(*a*) *The intensities of internal and surface stress at corresponding points are the same; also*

(*b*) *The distortions are proportionate, so that, taking account of these, the configurations remain similar.*

[The proposition is not true for gravity forces, for these increase as $N^3 : n^3$. Therefore the unit stresses due to them increase as the size of the machine increases. For this reason a large engine must have a more substantial-looking frame than a small one, and Nature provides an elephant with proportionally much clumsier legs than a deer. But gravity enters little into the design of a reduction gear.

The proposition is true when forces due to inertia are included, if the linear velocities of corresponding parts are the same; for instance, if in similar engines the piston speeds are the same. This is readily proved, but as it is of very slight bearing on the design of gears, I pass it over.]

Let us apply this to two exactly similar reduction gears the linear dimensions of which are as N : n. When they are under corresponding loads there will, by the foregoing proposition, be the same intensity of stress at each point, including that at the tooth contacts; the same proportionate yield of the bearings; the same proportionate deflection and torsion at each point of the pinion, &c.

It is important to notice particularly the action of the teeth. No two bodies bearing on one another ever have point or line contact. If so, the intensity of stress would be infinite. There is a small but calculable distortion which in all cases brings areas into contact. Thus, in teeth, it is never quite exact to speak of point or line contact. In two spur-teeth bearing from end to end there is actually a very narrow strip in contact. By proposition B (*b*), for the relative loads there supposed, the breadths of these strips will be proportional to the linear dimensions—that is, to the pitches—and as the lengths are proportional to the linear dimensions, the areas will be as $N^2 : n^2$; that is, in proportion to the total loads. Hence the intensities of surface pressures are equal, as proposition B (*a*) states, and similar teeth can bear loads per inch length proportional to the pitch. The presence of lubricating oil, keeping the surfaces from actual contact, diminishing friction, and increasing the effective breadth of the above strip, will greatly increase the allowable load. The amount of this increase will depend on the qualities of the oil used.

We may now extend proposition A. For if in one of the two similar gears some change is made in its proportions which is advantageous (or the reverse), the same proportionate change in the other gear will effect precisely the same advantage (or the reverse). Therefore:

Proposition C.—In any type of design of reduction gear there is one set of proportions which is better than any other.

Power Constant.

Let D = the diameter of pinion in inches.
L = total length of tooth-face in inches.
p = average pressure per inch length of tooth-face in pounds.
R = revolutions per minute of pinion.
P = horse-power transmitted.

$$P = \frac{\pi\ D\ R\ p\ L}{12 \times 33{,}300}.$$

For the best results, as Propositions B and C show, p and L are proportional to the linear dimensions—that is, to D. Hence

$$P = \text{Const.} \times D^3\ R, \text{ or}$$

$$\text{Const.} = \frac{P}{D^3\ R}.$$

We may write

$$\text{Power constant} = C = \frac{1000\ P}{D^3\ R}. \quad . \quad (1)$$

The factor 1000 is introduced to bring C to a value usually between unity and 10.

So far as I know, observation has not shown any detrimental action on the teeth at the highest peripheral speeds which have been used. Oil should be injected freely, striking the gear or pinion just before the teeth come into contact, so that it cannot be driven off by the high centrifugal force before performing its function. As the speed is increased at constant load, probably the oil film at the tooth contacts increases in thickness if the supply of lubricant is copious, since the time for its escape is diminished. If this is correct there is no condition connecting D and R, and thus affecting the free application of the above formula.

Hence, as I promised to show, D should be plotted on $\frac{P}{R}$ as abscissa, and it is a cubic parabola normal to the axis of the abscissæ at the origin.

The power constant is calculated from the diameter and revolutions of the pinion alone. By faulty design the gear, especially if of large diameter, might be given too much longitudinal elasticity, so that the rim would be displaced axially by the tooth pressure, especially if helical teeth with a large angle of helix are used. But ample longitudinal rigidity can readily be supplied. Its teeth will be made as strong as those of the pinion, or possibly a little thinner, as wear will affect the pinion teeth most. But its torsional and flexural rigidity are incomparably greater than those of the pinion, in the design of which these distortions determine the limiting proportions. Nor need we consider the effect on the action of the teeth of an increase in the size of the large gear, for that only makes the arc of contact longer to an unimportant extent. Hence the exclusive use of the pinion in calculating the power constant is fully justified. I will show in connection with data of gear performance how very important it is to effect safely a rise of this power constant.

Object of Reduction Gear Design and Conditions Limiting Power Constant Used.—We may now state the object which should usually be sought in designing reduction gears so as not only to find the proportions for any given type of design which will with equal safety allow of the highest power constant, but

To find that type of design and its proportions which will, for the same values of the factors of safety, allow of the highest power constant.

If we could secure the even distribution of pressure along all the tooth contacts, large powers could be transmitted through pinions of comparatively small diameter and great length. The limiting difficulties arise almost altogether from the impossibility of attaining this perfectly.

(*a*) All pinions sag between the bearings, tending to concentrate pressure on those parts of the teeth near the bearings.

(*b*) All pinions yield torsionally in transmitting the driving couple. In spur-gears, with straight teeth, these will become slightly helical and cease to fit the straight teeth of the gear. In double helical gears one helix is slightly wound up, increasing its helical angle, and the other is slightly unwound.

(*c*) The temperature of the pinion rises above that of the gear, principally from heat developed in its bearings. This increases the circumferential pitch of the pinion-teeth above that of the gear-teeth, and, in helical gears, also increases their axial pitch.

(*d*) The alignment of the axis of pinion and gear may not be proper. In gears with rigid bearings the misalignment allowable is extremely slight.

Let us take these in order.

(*a*) *Transverse Yield.*—Suppose a cylindrical bar, supported horizontally at two points, one at each end, and loaded uniformly.

Let

l = distance between bearings.
D = diameter of bar.
w = load per unit length.
y = maximum transverse yield.
E = Young's modulus of elasticity.

$$y = K \times \frac{w}{E}\left(\frac{l}{D}\right)^4,$$

where K is a constant depending on whether the beam is free at the ends, or fixed in direction at one or both ends, &c.

Hence it cannot be proper to fix on the pinion diameter D and the tooth pressure per inch and then calculate the length l required for a given power, unless we know that for the value of l thus arrived at y is negligible. Since y varies at l^4 there will be a very sharp limit of l/D beyond which it will be detrimental to pass.

To obviate this difficulty in the De Laval gear, with its long and very flexible pinion, two gear-wheels are used, on one of which the pinion bears upward and on the other downward, and, if equal power is run off each gear-wheel, the cross-bending forces are zero. I have been informed that when this condition of equal power is not fulfilled trouble is experienced.

Messrs. McLaren and Welsh make no remark on the difference of two and three bearings for the pinion. In one figure they show a pinion with three bearings in which the ratio of total width of gear-teeth to pinion diameter is 4.82; that is, for the right or left helix alone, a ratio of 2.41. (This last, of course, is nearly the same as the ratio of the distance between bearings to pinion diameter.) In another figure they show pinions with two bearings in which the ratio of width of gear-teeth to pinion diameter rises to 3.475. How many bearings the other pinions are supposed to have is not stated, though this is of extreme importance. I believe even 2.41 is too large a ratio for the best results, and the deflection for 3.475 at the same rate of loading is over four times as much.

Let us take the analogous case of a uniform beam simply supported at the ends, S_1, S_2, and uniformly loaded with w lb. per inch. This is shown by A, Fig. 2. The maximun transverse deflection is

$$y_a = 0.2652\ \frac{w}{E}\left(\frac{l}{D}\right)^4, \quad . \quad . \quad . \quad . \quad (2)$$

and the inclination at the supports, S_1, S_2, is given by

$$\frac{d\ y}{d\ x_a} = \frac{0.8488\ w\ l^3}{E\ D^4} \quad . \quad . \quad . \quad (3)$$

If now we put a support at S_3 at the centre of the beam, level with S_1, S_2, the configuration of the beam is now shown by B, and, from symmetry, it is fixed in direction at S_3. The length of each part is l/2 and the maximum deflection takes place at

M where

$$S_3\,M = 0.5785 \times \frac{w}{2}.$$

This deflection is

$$y_b = 0.1104\,\frac{w}{E}\left(\frac{l/2}{D}\right)^4, \quad . \quad . \quad . \quad (4)$$

and the inclination at the supports S_1, S_2 is

$$\frac{d\,y}{d\,x_b} = \frac{0.4244\,w\,\left(\frac{l}{2}\right)^3}{E\,D^4} \quad . \quad . \quad . \quad (5)$$

The ratio of the maximum deflection for two and three supports is

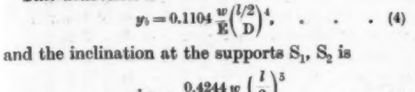
$$\frac{y_a}{y_b} = \frac{0.2652 \times 16}{0.1104} = 38.4,$$

and the ratio of the inclinations at the supports S_1, S_2 is

$$\frac{0.8488 \times 8}{0.4244} = 16.$$

Hence a deflection which is much too great can be reduced to a negligible quantity by introducing a third bearing, and as the pinion journals are bedded in their bearings with no load on the teeth, they will lie more fairly in them under load if there are three bearings.

Fig. 2. *Uniform Load of w Lbs. per Inch.*



Messrs. McLaren and Welsh state that "Messrs. the Parsons Marine Steam-Turbine Company, Limited, have proposed to increase the number of pinions engaging with one wheel, in order to keep down the width of the wheel-face, . . ." Their experience bears out the foregoing. The values now to be given further enforce these deductions from the formulæ.

The question of the difficulty of keeping three bearings aligned I will take up later. To illustrate by a particular case:

The experimental Melville and Macalpine gear* of 1909, afterwards referred to as "the experimental gear," had a pinion of 14 in. pitch diameter with three bearings, each helix being 20 in. long. The ratio h/D, where h is the length of one helix, was thus 1.43. This was kept small, so that all difficulty from deflection and torsion would certainly be avoided. It was put to extensive tests, at the expense of the late Mr. George Westinghouse, in the works of the Westinghouse Machine Company, East Pittsburg, Pennsylvania. The longest test was one of 40 hours' duration under constant load. The pinion speed averaged 1512 revolutions per minute and the brake horse-power 6048. This was the limit of boiler power available, but it was perfectly evident that it was far from the maximum safe load of the gear.

Let us approximate to the transverse deflection of the pinion. The analogy of a bar supported at three points and uniformly loaded along all its length hardly applies to any actual case, as the bearings are a considerable fraction of the whole length of pinion. A sufficient approximation can be arrived at by treating each helix as a beam supported at its ends, applying equation (2). At 6000 horse-power and 1500 revolutions per minute of pinion this gives a deflection of 3.43×10^{-5} in., taking $E = 29 \times 10^6$ lb. per sq. in. We now know that the ratio h/D could have been raised to 2, and more than double the load borne with perfect safety, giving a power constant of nearly 3. Doubling the load doubles $w\,l$, and the deflection, which is proportional to $w\,l^4$ ($= w\,l \times l^3$), is raised to $3.43 \times 2 \times \left(\frac{28}{20}\right)^3 \times 10^{-5} = 18.8 \times 10^{-5} =$ about $\frac{1}{5000}$ in. If the teeth were perfectly rigid and cross-bending the only distortion, this would lead to point contact and an opening of contact maximum near the middle of each helix, thus completely upsetting the initial supposition of uniform loading. But it was estimated that the teeth of this pinion and gear together had an elasticity which would make them yield in the neighbourhood of $\frac{1}{1000}$ in. for a pressure of 1000 lb. per inch. So that the calculated deflection of $\frac{1}{5000}$ in. would not seriously affect the uniformity of loading.

The result seems also to indicate that, even if there were no other distortion, cross-bending alone would make it inadvisable to increase h/D very much beyond 2, since the yield increases as $(h/D)^4$. Estimation of the torsional error will strongly emphasise this remark. Even if we knew the best ratio, it would be well to keep slightly within it, as practically the same load could be transmitted with decidedly diminished distortion.

Let us now estimate the deflection for these two powers and values of h, supposing only two bearings. With $h = 20$, allowing for the clearance of the hob between the helices and clearance between the helices and bearings, the distance between the inner ends of the bearings would be at least 43 in. If we apply equation (2), putting $l = 43$, we considerably under-estimate the deflection, as there is considerable cross-bending in the pinion at the inner end of each bearing. In the experimental gear the two end bearings were 18 in. long and the centre one 24 in. If in the two-bearing gears at 6000 horse-power we suppose these to be 20 in. long, and at 12,000 horse-power 24 in. long, we very considerably raise the pressures, especially in the latter case, from those of the experimental gear. I shall also apply equation (3) to calculate the inclination of the journal and its rise in the length of the bearing.

Power.	R.P.M. of Pinion.	Length of each Helix.	Length between Bearings.	Length of each Bearing.	Deflection.	Inclination of Journal.	Rise of Journal in Length of Bearing.
		in.	in.	in.			
6,000	1500	20	43	20	6.82×10^{-4}	5.075×10^{-5}	1.015×10^{-3}
12,000	1500	28	59	24	3.52×10^{-3}	1.91×10^{-4}	4.58×10^{-3}

The deflection in the upper line has increased greatly from that for three bearings, and, as we shall see later, the torsional error added nearly doubles this value. That it is entirely outside of practical limits may be doubted if we calculate the torsional error for floating-frame gears running at the highest-power constant which has been successfully used. But, still, it is very large, and I think the span of the bearings could be diminished with advantage.

That given in the lower line is more than five times as great and is wholly impracticable. Hence the power which can be transmitted by a two-bearing pinion is far under what the same diameter can transmit if furnished with a third bearing.

The rise of journal, in the bearing length, of $\frac{1}{1000}$ in. is also excessive. If the journal were lying fair in its bearing the oil film would probably be from $\frac{1}{1000}$ in. to $\frac{1}{2000}$ in. thick. Hence a rise of $\frac{1}{1000}$ in. would mean that the bearing pressure was localised over a short length at the helix end. But no doubt this could be improved by fitting journals with a spherical support which would automatically adjust their alignment.

But it should be carefully noted that the difficulty from deflection of the helices cannot be influenced by any mode of suspension of the journals or by giving freedom in the bearings.

It might be replied that if the fitting of the teeth were finished under full torque almost any error of deflection could be allowed for, and this applies not to deflection alone, but to errors due to torsion and excess of temperature of the pinion also. This would not only mean finishing under full torque, but fitting the teeth progressively under a greater and greater torque, which would be a long and costly process, and it in no way overcomes the difficulty of varying deflection under varying load and localised pressure under all but full load. Besides, in the case of large powers it would often be impossible to apply nearly full torque in the shop. The only practical procedure is to design a gear in which these various errors are so small that if uniform distribution is secured at light load it will not be upset seriously at the highest power.

(To be continued.)

* See ENGINEERING, vol. lxxxviii., page 377. The present article amplifies much that was said in this earlier article, and consequently there is some repetition. The details of design, shown there clearly by drawings, are not repeated.

LITERATURE.

(1) *Tacheometer Surveying.* By M. E. YORKE ELIOT. Illustrated. London: E. and F. N. Spon, Ltd., 1916. [Price 5s.]

(2) *The Elements of Surveying and Geodesy.* By WILLIAM CHARLES POPPLEWELL, M.Sc. Illustrated. London: Longmans, Green and Co. 1915. [Price 7s. 6d.]

SURVEYING as a practical science has gained immensely from the perfecting of optical instruments and the accuracy with which a circle can be divided. Full advantage has been taken of these appliances to facilitate operations in the field. Small and readily portable theodolites with finely graduated arcs have made possible that rapid tacheometrical method of surveying in which the tedious measurement by chain is superseded by observing the image of an object of known dimensions in the focal plane of a carefully adjusted telescope. At the same time, direction is given by reading horizontal angles, and the final position can be derived by a method of polar co-ordinates. Mr. Eliot's book now before us forms a well-considered introduction to this method of surveying, and possesses some very satisfactory features. From the first, the author proposes to enable a student to teach himself and recognises the limits which such a plan imposes. He wisely confines his instruction to inculcating general principles, and does not embroider his subject by discussing minutiæ that find but little place in practical work. He keeps before the student the steady pursuit of distinct methods, and does not overload these by excursions into theoretical considerations that do very little to assist the attainment of a high standard of accuracy. The self-taught pupil, working alone, is necessarily at a disadvantage when compared with one who can draw on the experience of a teacher for the supply of precise information on particular points, or the removal of difficulties as they arise. Such a one does not need to be handicapped by the insistence on details that may make for completeness, but whose relative importance he is incapable of estimating correctly. Many writers of student text-books seem to think it necessary to describe every possible way of obtaining a result; if the object is to determine the latitude of a place, for example, they are not content to let the student practise one method, but must set before him half a dozen bewildering propositions, that cannot but confuse an ill-equipped pupil who has no other guide than his text-book.

Mr. Eliot does not fall into this error. He recognises that trustworthiness is of greater importance than versatility, that observation for the most part consists in the repetition of the same operations, and that the more mechanical an observer can become the less chance is there of accidental error. He gives sound advice when he recommends the beginner to adopt a routine method in handling his tools, and to adhere to it. The same counsel might be given with regard to observations, for practical surveying does not lend itself to trying experiments, however interesting.

Another good feature is the thoroughness with which the simplest examples are worked out, such as the survey of a simple enclosure or the measurement of difference of level. A methodical continuity is maintained throughout, and the student should feel that in one particular instance all the information possible has been extracted.

The determination of level by tacheometrica methods, properly so called, necessarily involves some examination of the theory of the instrument. This is made as simple as possible, and it is a pleasure to find the author recommending the use of the slide-rule for the purpose of computing the corrections that involve trigonometrical functions. He goes further still, and gives directions to enable students to construct a simple specimen that should go far to simplify the theory of such instruments. There is a slight falling off when it becomes necessary to solve a plane triangle, and we have to face the unnecessary superfluity of seven-figure logarithms. Perhaps the author would urge that it is not possible to derive products, consisting of five or six significant integers without extending the mantissa to this length. But what necessity is there to go to the apparent accuracy of a

THE PARIS MOTOR-BUSES IN WAR SERVICE; THE DE DION-BOUTON ENGINE.

(*For Description, see opposite Page.*)

Fig. 14.

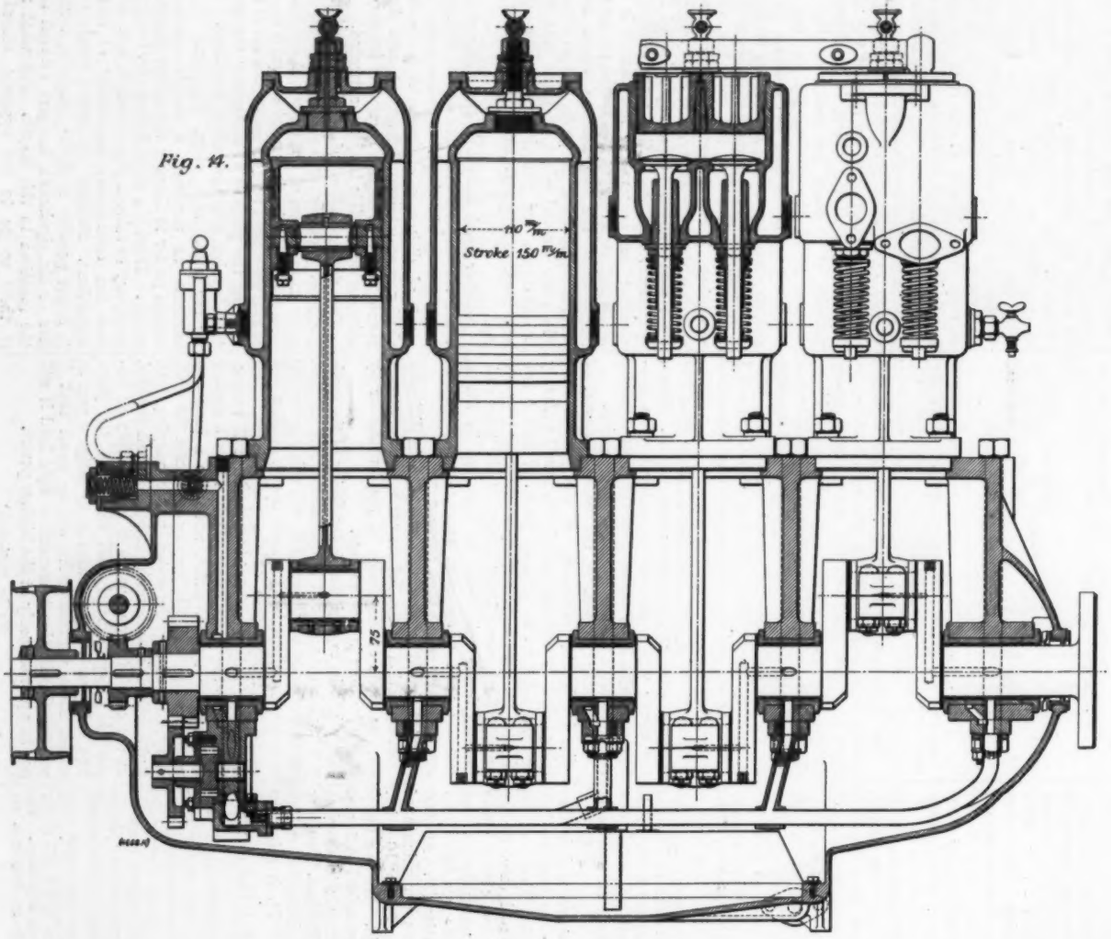
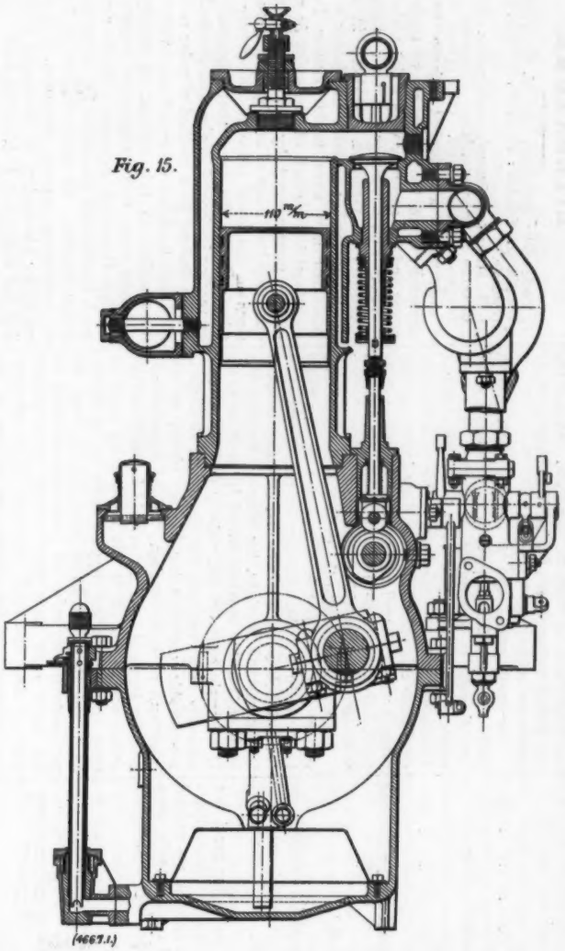


Fig. 15.



hundredth of a foot when the original data are faulty by a greater extent? In estimating distances of moderate length by stadia lines, the author states that the error should not exceed $\frac{1}{1000}$ of the distance measured. This degree of accuracy may have been reached in some favourable cases, but $\frac{1}{800}$ would be nearer the truth in the majority of measurements, and in any case calculations to a small fraction of an inch are not warranted. This apparent accuracy is the less defensible as the author permits the use of a planimeter in estimating areas where approximate results are useful. Here, again, the number of figures employed is excessive, and by suggesting a degree of accuracy that is unattainable by such procedure may do a disservice to the pupil. The diagrams are well and clearly drawn, and it is an excellent idea to illustrate the several processes, including contouring, by reference to an actual case and to carry the work through systematically. The book seems very free from errors, but there is rather an important misprint at the bottom of page 69 which may puzzle the student.

Mr. W. C. Popplewell's work is more ambitious, but we cannot say more satisfactory He aims at providing a comprehensive view of the subject of geodesy in its wider sense "in order to provide students and others with such information as may lead to a sound knowledge of the fundamental ideas involved." He is perfectly aware of the advantages to be obtained from personal instruction and contact with the experienced teacher, but considers that the principles of the science, and to some extent the theory of the instruments and method of use, can be acquired from treatises. This may be true, but we cannot conceive that anyone whose acquaintance with the subject is derived solely from book knowledge would be engaged in the intricate and delicate work of geodesy, involving the measurement of base lines and the processes of extensive triangulation. It is difficult to see therefore that any advantage is gained by treating in the same work the elementary methods of chain measurement, and the location of a point on the earth's surface referred to fundamental co-ordinates. If we add that the author has chapters on hydrographic and underground surveying, it will be evident that in his effort to be "compre-

THE PARIS MOTOR-BUSES IN WAR SERVICE; THE DE DION-BOUTON ENGINE.

Fig. 16.

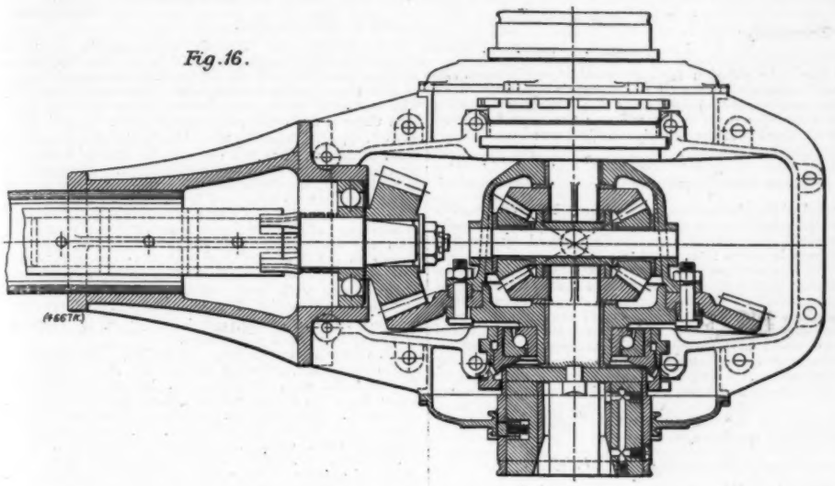
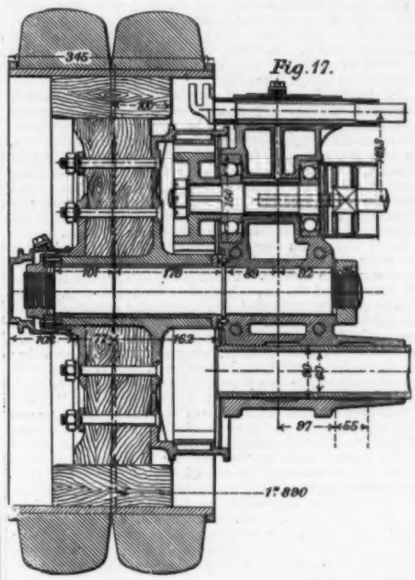


Fig. 17.



hensive" he may not escape the charge of being superficial.

In the first chapter of Mr. Popplewell's book is described the process of chain surveying, the author here travelling over ground that many have made familiar and endeavouring to impart an element of novelty, by giving the facsimile of a page from an actual field-book. Thence we are introduced to compass measurement and the well-worn paths of "traversing." There is here little scope for originality, but the explanations should prove clear and useful.

We would ask the author to consider, however, whether there is any advantage in referring to such minute sources of error as the magnetic diurnal variation. Can one imagine a surveyor's compass so nicely constructed, so accurately divided, and so efficiently used as to show the small displacements the needle undergoes from this cause? Mr. Popplewell truly says that the variation "need not be taken account of for ordinary work." But in what kind of surveying work would it be applied, and are the data for computing the correction sufficiently well known to permit it to be made with accuracy?

The chapters on the plane table, levelling and contouring are uniformly good and sufficiently thorough; that on the theodolite, giving ample directions for making adjustments and detecting errors, is evidently written with knowledge derived from wide practical experience.

At the ninth chapter the subject of geodetic measurement is introduced and the book ceases to be satisfactory. Problems of far greater delicacy than those in the preceding part are attacked, while the amount of information supplied is very much curtailed and not up to date. In the measurement of base lines, on whose importance the author rightly insists, we have put before us various devices that Bessel and Borda imagined, or General Ray may have used, but no mention is made of such recent measurement as that at Lossiemouth.

A more important defect in a text-book intended for the instruction of students is the failure to recognise the revolution effected in linear measurement by the introduction of the Jäderin apparatus, whereby the reduction in time in measuring a definite length, with the accuracy demanded in geodetic work, is reduced in the proportion of 1 : 10. The Eötvos torsion balance has materially assisted in increasing the accuracy of base line measurement, but similarly no mention is made of this apparatus.

Again, the remarks on the determination of longitude and latitude betray a want of familiarity with the methods in actual use; but possibly we are doing the author an injustice, and what has the appearance of defects of information may be deliberate suppressions in order to keep the book within moderate limits.

BOOKS RECEIVED.

Electrical Apparatus Making for Beginners. By ALBERT V. BALLHATCHET. London: Percival Marshall & Co. [Price 2s. net.]

The Tropics, their Resources, People and Future: a Description of the Tropical Lands of Africa, Asia, Central and South America, Australasia and the Pacific: their Natural Products, Scenery, Inhabitants and Industries, and the Possibilities of their Future Development. By C. R. ENOCK, C.E., F.R.G.S. With 54 Illustrations and Maps. London: Grant Richards, Ltd. [Price 16s. net.]

Elementary Sanitary Engineering: Course of Instruction for Indian Sanitary Inspectors. By Major GEORGE BRANSBY WILLIAMS. Calcutta: Thacker, Spink and Co., Government Place. [Price 5 rs. net.]

Telegraph Engineering: a Manual for Practicing Telegraph Engineers and Engineering Students. By ERICH HAUSMANN, E.E., Sc.D. London: Constable and Co., Ltd. [Price 12s. 6d. net.]

The Motor-Car Red Book, 1916; containing a List of Motor-Cars and Light Cars Manufactured or Sold in the United Kingdom, 1910–1916. Compiled by W. C. BERSEY and W. V. FOUCARD. Also *A List of Motor-Cycles, Commercial Motor Vehicles, Marine Motors and Aircraft.* London: Technical Publishing Co., Ltd. [Price 5s. 4d. net, post free.]

Pioneer Railway Engineering. By HERBERT CHATLEY, D.Sc. (Eng.). London: Technical Publishing Company, Ltd.

Employers and Workmen: a Hand-Book Explanatory of their Duties and Responsibilities under the Munitions of War Acts, 1915 and 1916. By THOMAS ALEXANDER FYFE. London and Edinburgh: William Hodge and Co. [Price 2s. 6d. net.]

A Text-Book of Practical Physics. By H. S. ALLEN, M.A., D.Sc. and H. MOORE, A.R.C.Sc., B.Sc. London: Macmillan and Co., Ltd. [Price 8s. 6d. net.]

Hydraulic Flow Reviewed: a Book of Reference of Standard Experiments on Pipes, Channels, Notches, Weirs and Circular Orifices, together with New Formulæ relating thereto. By ALFRED A. BARNES, A.C.G.I. London: E. and F. N. Spon, Ltd.; New York: Spon and Chamberlain. [Price 12s. 6d. net; post free 12s. 11d. United Kingdom, 13s. 3d. abroad.]

A Treatise on Electricity. By F. B. PIDDUCK. Cambridge: The University Press. [Price 14s.]

Wireless Telegraphy and Telephony: a Handbook of Formulæ, Data, and Information. By W. H. ECCLES, D.Sc., &c. London: *The Electrician* Printing and Publishing Company, Ltd.; Australasia: John Wyatt, 313–315, Little Collins Street, Melbourne; Japan: Z. P. Maruya and Co., Tokyo, Yokohama, &c. [Price 12s. 6d. net.]

THE PARIS MOTOR-BUSES.

(*Concluded from page* 344.)

IN the earlier portion of this article we dealt with the progress made during recent years in the construction of motor-buses for dealing with the Paris street traffic, and pointed out that those vehicles which had been commandeered by the French military authorities since the outbreak of hostilities were giving most satisfactory results in war work. We also gave an illustrated description of the mechanical parts designed and built by Messrs. Schneider and Co. for the thirty-five passenger type of vehicle.

The vehicle which we mentioned as having been designed for carrying thirty-one passengers is mounted on a De Dion-Bouton chassis, and is driven by a four-cylinder engine, illustrated in section in Figs. 13 and 14, on the opposite and present pages. The engine is placed beneath the driver's seat. The cylinders are 110 mm. (4.3 in.) bore and 150 mm. (5.9 in.) stroke. The power developed is 30 horse-power at 1000 revolutions. As in the type already described (the engine built by Messrs. Schneider for the omnibus service), ignition is by high-tension magneto, the advance of the spark not being adjustable. The carburettor is of the double-jet type. The cylinders are fired in the order 1, 3, 4, 2. The control is by accelerator pedal, the engine speed being limited by a governor. The cooling of the engine is by thermo-syphon and the lubrication by forced feed. The radiator is similar to the one fitted to the 35-seat vehicle.

The De Dion-Bouton motor-bus is provided with a plate-clutch, operated in the usual way by a foot-lever. The engine is fitted on a cradle which rests at three points on the cross-members fitted to the longitudinals of the chassis. In this type of motor-bus, also, there are three forward speeds, with direct drive on the third speed, and one reverse. The differential gear is illustrated in Fig. 15. The back wheels are operated by spur-pinions which engage the internal teeth of two rings which are bolted to the wheels, as shown in Fig. 16. The back axle consists of a tube fitted in two cast-steel axle-heads, the latter being connected to the rear springs. The front axle is a drop-forging of steel. Steering is by worm and segment, and is irreversible. There are two brakes, a differential brake and a brake on the back wheels similar to the one on the Schneider chassis.

The De Dion-Bouton chassis is 6.910 m. (22 ft. 8 in.) long, 0.946 m. (37.2 in.) wide in front and 2.160 m. (7 ft. 1 in.) wide at the back. The wheel base is 3.560 m. (11 ft. 8 in.). The total width outside the front axle-caps is 2.128 m. (7 ft.) and 2.245 m (7 ft. 4½ in.) outside the back axle-caps; the width outside the wheels is respectively 1.915 m. and 2.235 m. (6 ft. 3 in. and 7 ft. 4 in.). The wheels have the same diameter as those of the Schneider chassis. The chassis weighs 3470 kg. (3 tons 8 cwt. 1 qr.), of which 1770 kg. (1 ton 14 cwt. 3 qr.) is carried on the front axle.

The vehicle empty and ready for service weighs 5070 kg. (4 tons 19 cwt. 3 qr.), of which 3100 kg. (3 tons 1 cwt.) is carried on the back axle. With the full complement of passengers the weight is 7160 kg. (7 tons 3 qr.), of which 2085 kg. (2 tons 1 cwt.) is on the front axle. The speeds on a level, when the motor runs at 1000 revolutions, are 6 km., 11 km. and 20 km. (3.75, 6.85 and 12.4 miles) per hour.

AMERICAN RAILS.—The exports of rails from the United States last year were 391,491 tons, as compared with 174,680 tons in 1914, and 460,553 tons in 1913. The largest shipments last year were to Asia and Oceania. There was a very appreciable falling off in the exports to Canada, Mexico, Japan, and South America. On the other hand, the imports of rails into the United States last year were 78,525 tons, as compared with 22,571 tons in 1914, and 10,408 tons in 1913. The value of last year's imports was 2,088,532 dols., thus giving an average of 26.59 dols. per ton.

"ON THE WHIRLING SPEEDS OF LOADED SHAFTS."

To the Editor of Engineering.

SIR,—I am gratified that my article should have called forth such an interesting and important letter as that published in your issue of April 21, from so eminent an authority as Dr. Stodola, and all interested in this problem of whirling speeds will surely welcome the information which it contains.

Dr. Stodola's method of proving my result wrong is somewhat curious. By a different type of investigation from that I have employed, he shows that a distinctly different—although corresponding—result is fallacious. He seemingly argues from this that my result is also fallacious, and attributes the considerable difference between the two numerical values to my having considered the centre of gravity of the rotating mass as always in the plane of bending. The difference would seem to be, however, due to a much more fundamental cause.

But I note with some surprise that Dr. Stodola does not refer to the purely physical idea of this critical speed which he decries. I had always supposed that the real strength of the hypothesis I had advanced lay quite outside the mathematical treatment, the result of which was only to be looked upon as confirmation of a simple idea. The full treatment was gone into because it gave the "new" value and the ordinary value simultaneously; but all the demonstration that seems to me to be necessary is contained in the few lines stated by Professor Morley, in his letter in your issue of March 24. The "new" critical speed is merely a matter of synchronism; an agreement between the period of revolution and that between the period of revolution and that of the natural period of the loaded shaft as reduced by rotation, according to the law established by Dr. Chree. I had taken that the necessary disturbance was caused by the weight itself, and still find it impossible to believe that the weight has no such effect. But, in any case, the disturbance might arise from the rotation quite apart from this; it is always assumed that a critical speed is reached when the period of revolution is in agreement with that of some natural vibration.

It should be obvious, therefore, that this "new" value depends altogether on the truth of the law established by Dr. Chree, and it will be found, in reality, that Dr. Stodola raises a point which transcends in importance the mere question of the validity of my mathematical work, for (and it is not quite clear that he has realised this himself) his result really questions the truth of this law.

This has been pointed out to me by Dr. Chree, in a reply to a request from me for enlightenment in the matter of Dr. Stodola's letter, and, as he has kindly granted me permission to publish it, I have great pleasure in giving his valuable letter in full herewith.

Dear Mr. Kerr,—At present, like most other people in this country, I have more than my normal amount of official duties, and cannot well spare the time necessary to consider the legitimacy of your work, on page 225 of ENGINEERING, or the basis for Dr. Stodola's criticisms. A shaft does not consist of a number of isolated discs acted on by separate forces, but is an elastic solid, throughout every part of whose interior certain body equations apply, and subject to certain surface equations. The action over any particular cross-section depends on what is happening in the material at either side of it.

Such an equation pair as

$$m\ddot{x} = m x\omega^2 + 2 m \omega \dot{y} - a (x + p) - W \sin \omega t$$
$$m\ddot{y} = m y\omega^2 - 2 m \omega x - a (y + q) - W \cos \omega t$$

really applies to an isolated mass m, whose co-ordinates are x and y relative to a pair of axes rotating with angular velocity ω, acted on by a force whose components along the instantaneous positions of the axes are

$$- a (x + p) - W \sin \omega t$$

and

$$- a (y + q) - W \cos \omega t$$

Whether such an equation really applies to a rotating shaft I am unable to judge. There are so many tacit assumptions. If we suppose $w = o$ we have

$$m\ddot{x} + a (x + p) = o$$

and if p is a constant we get a period $\frac{2\pi}{\omega_k}$, where $\omega_k^2 = \frac{a}{m}$.

This gives a single period, and so is obviously not a complete representation of what happens in a rotating shaft, which has a series of periods. In this respect it has the same limitations as the ordinary Rayleigh method for frequencies.

If, waiving the question of their real applicability to the problem in question, we consider the solution of Dr. Stodola's simultaneous equations:—

$$\left.\begin{aligned}\ddot{\xi} - (\omega^2 - \omega_k^2)\,\xi - 2\,\omega\,\dot{\eta} &= - g \sin \omega t \\ \ddot{\eta} - (\omega^2 - \omega_k^2)\,\eta + 2\,\omega\,\dot{\xi} &= - g \cos \omega t\end{aligned}\right\}$$

it is obvious on inspection that the particular solution is of the type

$$\xi = A \sin \omega t, \eta = B \cos \omega t$$

where A and B are constants given by

$$A (2\,\omega^2 - \omega_k^2) - 2\,\omega^2 B = g = B (2\,\omega^2 - \omega_k^2) - 2\,\omega^2 A$$

or

$$B = A = - g/\omega_k^2$$

the result reached by Dr. Stodola.

For the general solution, D representing d/dt, we have

$$[D^2 - (\omega^2 - \omega_k^2)]\,\xi - 2\,\omega\,D\eta = o$$
$$2\,\omega\,D\,\xi + [D^2 - (\omega^2 - \omega_k^2)]\,\eta = o$$

Thus, if we suppose a wholly real natural vibration of period $2\pi/_k$, we have

$$\{k^2 + (\omega^2 - \omega_k^2)\}^2 = (2\omega k)^2$$

or

$$(k \mp \omega)^2 = \omega_k^2$$

Presumably

$$k + \omega = \omega_k \quad . \quad . \quad . \quad . \quad . \quad (1)$$

is the only solution having practical application. It would thus appear that if Dr. Stodola's equations really represent the actual conditions, the frequency equation for a rotating shaft is (1), whereas the type I derived by application of the Rayleigh method was

$$k^2 + \omega^2 = \omega_k^2 \quad . \quad . \quad . \quad . \quad (2)$$

In either case $\frac{2\pi}{\omega k}$ represents the natural (fundamental) period of the shaft when not rotating. Thus presumably Dr. Stodola does not question the accuracy of the results obtained for the ordinary whirling period by treating the problem as a vibrational one.

The question really at issue seems to be whether the natural period of a shaft when rotating is given by (1) or by (2). The mathematical simplifications introduced in deducing either (1) or (2) are so considerable that experiments on a simply supported shaft would seem much to be desired. In either case we have k decreasing as ω increases, and ultimately vanishing when $\omega = \omega_k$.

As to a sensitive lower period, if (1) is correct, we have

$$k = \omega \text{ when } \omega = \omega_k/2,$$

while, if (2) is correct,

$$k = \omega \text{ when } \omega = \omega_k / \sqrt{2}.$$

When $k = \omega$ we should on general principles expect that any suitable force whose period was ω would be specially effective in setting up forced vibrations. If the e.g. of the cross section is naturally out of the geometrical axis, the weight seems a type of force one would naturally expect to be effective, but there might be a variety of forces having their source in the rotation and so sharing its period.

If, as I understand Dr. Stodola to say, a tendency to irregular motion has been noticed in different cases both at $\omega = \omega_k/2$, and at $\omega = \omega_k/\sqrt{2}$, it is certainly a curious fact. Assuming it true, there must be some special virtue, or perhaps vice would be the proper term, in both velocities. This emphasises what I said in my letter to ENGINEERING about the expediency of experiments on a variety of types of turbine.

There is, of course, an obvious objection to either (1) or (2) as a general representation of the facts. It is experimental knowledge that a shaft can run at above the critical speed answering to ω_k, while according to (2) if ω exceeds ω_k, we should have k^2 negative, *i.e.*, no natural vibration would be possible. But this only means that in arriving at (2) we tacitly assumed the natural vibration to be the fundamental one. Taking, for example, the shaft supported at its two ends, we assumed the displaced axis to be entirely on one side of the undisturbed axis. For velocities exceeding ω_k we should have to take for the hypothetical displacement one appropriate to the vibrations higher than the fundamental. For the next vibration to the fundamental we have a node—*i.e.*, zero displacement—at the centre of the length.

What really happens in the immediate neighbourhood of a critical speed is very possibly outside the ordinary range of mathematics. The ordinary mathematical equations tacitly assume the displacements very small, and any equations based on such a hypothesis cannot be implicitly relied on when displacements tend to become large.

If (1) is the correct equation, and not (2), there must, of course, be something wrong in the application I have made of Rayleigh's method to rotating shafts. Conversely, if (2) is correct, there would seem to be something amiss with Dr. Stodola's equations. It is comforting that there is no difference between the two results so far as the ordinary whirling speed is concerned, but the question seems important for the explanation of any special phenomenon at lower speeds.

Yours very truly,
C. CHREE.

This letter, I think, demonstrates clearly that Dr. Stodola's arguments are not quite conclusive, unless he can show that there is a fundamental error in the establishment of the result arrived at by Dr. Chree in 1904.

I note with interest Dr. Stodola's deduction from Föppl's equations regarding rotation about the gravitationally deflected position. It will be remembered that this was pointed out by Professor Jeffcott, but it is to be noticed that the result arrived at bears out my contention—in reply to Professor Jeffcott—that, if the motion is to be studied as a rotation about this position, gravity must be neglected in the analysis. Also, I hardly think it is right to make the statement "and there is no critical speed, except the ordinary one," apparently based on this manipulation of Föppl's equations. These equations do not show the effect of rotation on the vibration frequency, and therefore could hardly be expected to indicate a critical speed entirely dependent on such effect.

Finally, it will be noted that Dr. Stodola makes the extremely interesting admission that vibration troubles do arise at definite speeds much lower than the ordinary critical speeds. Some of your correspondents seemed inclined to be doubtful regarding this, and to treat my case as exceptional. I think that this statement by Dr. Stodola will be convincing as to the practical importance of this question. The fact that the occurrence has been noticed both when $\omega = \omega_k/2$ and when $\omega = \omega_k/\sqrt{2}$ is most perplexing, and provides no assistance in the matter of theoretical treatment.

I am, Sir, yours faithfully,
WM. KERR.

Airdrie, April 29, 1916.

P.S.—I have just seen the short article on "The Critical Speeds of Shafts," and the letter from Mr. Carter in your issue of April 28, although, I am afraid, unable to give them proper consideration in the time available. The author of the former seems to agree with my claim that there is a theoretical reason for this "new" value at $\omega_k/\sqrt{2}$, and states the basic idea in the simple manner that, somehow, does not seem to be clearly envisaged by those who are adversely criticising it. The explanation there given of the fact that the vibration at this speed may not be excessive is instructive, and, indeed, the consideration of the problem from the point of view of constancy of angular momentum is distinctly valuable. Also the statement "and many builders of turbines have also noted serious disturbance at about this proportion of the true critical speed" is worthy of emphasis. Taken along with Dr. Stodola's statement and the particular case which I have observed, the practical evidence as to a critical speed at $\omega_k/\sqrt{2}$ is certainly attaining important dimensions.

Mr. Carter's letter is very interesting. His treatment and result are somewhat similar to those given by Dr. Stodola, and, consequently, he should find the letter from Dr. Chree, which I have embodied herein, of interest. But while Dr. Stodola considers this critical value at $\omega_k/2$ entirely fallacious, Mr. Carter seems to think it valid enough, although unimportant. Like Dr. Stodola, Mr. Carter considers the case where the centre of gravity of the wheel has two degrees of freedom; but since the result I had obtained still appears, even if the centre of gravity is taken as coincident with the centre of the deflected shaft, I conceived that there was no serious fault involved in assuming the centre of gravity as always in the plane of bending. Also, such assumption is not incompatible with the necessary treatment of the shaft as subject to pure bending.

In connection with this critical speed at $\omega_k/2$, I might remark that on several occasions I noticed distinct, but feeble, vibrations, with the 250-kw. turbine, at almost exactly this value. But load tests were being run at those times with the turbine coupled up to a water brake, and I attributed the occurrence to some fault in alignment, the connection being frequently broken as steam friction tests alternated with load tests. The disturbance was not indicated at all when the turbine was run disconnected, and I only remark upon it because this $\omega_k/2$ value has become somewhat prominent. Indeed, the vibration was in no sense comparable with that at $\omega_k/\sqrt{2}$, where it occurred with great suddenness and intensity.

The varied aspects of this problem which are being presented in the course of this discussion are undoubtedly of great value, but lead, I must admit, to some confusion of thought in the mind of one who is honestly, but with inadequate attention, endeavouring to grasp all the points advanced. Perhaps a full and rigorous treatment of the subject will disclose theoretical evidence of critical speeds at both $\omega_k/\sqrt{2}$ and $\omega_k/2$, the latter as a secondary effect of gravity, unimportant as compared with the former, which is itself of practical but minor importance relatively to the condition of complete instability corresponding to ω_k. In any case, methods of treatment which hide the $\omega_k/\sqrt{2}$ value, and indicate only the $\omega_k/2$ value, would seem to be unsatisfactory in view of the practical evidence so far adduced.

W. K.

To the Editor of Engineering.

SIR,—In determining the critical speed of a rotor there is always some uncertainty. For instance, it is difficult to forecast the stiffening effect of a ring or disc shrunk or pressed on to the shaft, or the damping effect of discs or laminations such as are sometimes used with alternator rotors. More difficult still is calculating the critical speed when the turbine and alternator rotors are connected by a rigid coupling.

The discussion, however, does not deal with the determination of the critical speed, but with the performance of the rotor before the first critical speed is reached. One hesitates to be dogmatic, but I must lay down with insistence that Mr. Kerr and your various correspondents are attempting to create a mystery where none exists. Vibrations occurring before the first critical speed are frequently encountered, but I never knew of a case that could not be remedied by some mechanical adjustment. The principal causes of such vibrations are as follow:—

(1) *Bad Dynamic Balance.*—The rotor balance may be good statically, but bad dynamically, because of lack of symmetry in any given plane. Thus, an out-of-balance at one end of the rotor may have been corrected by a chance variation or by adding balance-weights at the other end. The result is a couple tending to give rise to a forced double transverse vibration in the shaft. Vibration due to this cause usually becomes manifest at a particular speed, and becomes more marked as the speed is increased.

(2) *Undue or Uneven Bearing Clearance.*—It is surprising to me that such well-known authorities on the subject as Dr. Chree, Professor Morley, and Professor Stodola, do not find room in their philosophy for the possibility of variations in the position of the vibration nodes, with a given static deflection affecting the critical speed. It is usual to allow a running clearance of about one-thousandth inch for each inch of journal diameter. Such a clearance makes it possible for the vibration node to be located beyond or inside the centre of the

bearing, and so reduce or increase the value of the critical speed. Affecting the critical speed in this way, however, is unlikely unless the rotor is decidedly out of balance, or unless the bearing clearance is excessive or not uniform. Such vibrations may appear at a speed considerably below the critical speed, and may not disappear until a speed considerably in excess of the critical speed has been reached.

(3) *Inalignment of Bearings and of Coupling.*—Any lack of alignment of the bearings, and more particularly of the coupling when it is of the rigid type, is liable to cause vibration. In some cases the vibration may occur at a particular speed and disappear at a higher speed; in other cases the vibration may not start until the load is placed on the machine, and even then not commence until the load has reached a certain value, and in at least one case that I have known the vibrations disappeared when a greater load was applied. Vibrations due to this cause are usually very violent, involving the immediate shutting down of the plant.

(4) *Looseness of Some Part of the Rotor.*—One frequently encounters cases in which, due to faulty design or workmanship, rings or discs pressed on to the shaft come loose at a particular speed on account of the stress due to the centrifugal force exceeding the stress caused by the press fit. Vibrations due to this cause begin at a definite speed, and usually increase in magnitude as the speed is increased. Cases, however, occur of turbo-alternator rotors in which steel rings or bands encircling the end windings do not come into intimate contact with all the coils when the machine is standing. At a certain speed one of the coils may move outwards until it comes into contact with the ring, thus causing a vibration to be set up that may disappear at a higher speed on account of another coil then similarly moving outwards and balancing the first one.

(5) *Internal Strains in the Shaft.*—It is possible to get very curious vibrations or even actual whirling at speeds below the first critical speed in shafts or rotors that have present in them considerable internal strains. In such cases also it is well known that the vibrations from this cause may not occur until the load reaches a certain value, but then continue until the speed has practically fallen to zero. In other cases vibrations due to this cause may occur at a certain speed, and disappear at a higher speed. It is obviously of the greatest importance that high-speed shafts should be thoroughly freed from all initial stress. After forging they should be annealed, and after rough-turning should be re-annealed and then oil treated.

(6) *Unequal Expansion.*—Unequal expansion of parts of the turbine rotor, due to various causes, may give rise to vibrations. As a rule it is not until the turbine has been running for some time, and until a fair amount of load is taken from it that trouble of this kind is experienced.

Speaking with the knowledge of having observed the critical speed of many scores of high-speed shafts, I should like to say very definitely that if any vibration is observed before the first critical speed is reached, the man to be sent for is the engineer, and not the mathematician. There is, however, still plenty of scope for the mathematician on this subject, and I should like to take this opportunity of bringing the requirements of the designer to his notice. Within recent years there has arisen the practice of using a rigid coupling between the alternator and the turbine, in some cases with two bearings for the alternator and one for the turbine, and in others with two bearings for each. Also, a further complication has been introduced by the practice adopted by some turbine builders of raising the outer alternator bearing to bring the faces of the coupling parallel before bolting them together. Professor Morley's most excellent graphical method of computing the critical speed is not applicable in such cases, and the calculation is a lengthy and tedious process. If Professor Morley or some other mathematician could devise a graphical method for dealing with these new conditions, he would earn the gratitude of many harassed designers.

In conclusion, I should like to add that if Mr. Kerr's research has not led to any definite achievement, it will always remain an interesting contribution to the mathematics of this subject.

Yours faithfully,

S. F. BARCLAY, Ph.D., B.Sc.

River Don Works, Sheffield, May 1, 1916.

THE DEVELOPMENT OF THE MILITARY AEROPLANE.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Lanchester's answer to my criticism can hardly be said to be satisfying. He says, with regard to the detail of my objection, that a 5-ft. model biplane weighing 31 lb. requires, for least gliding angle, the same speed—viz., 60 miles—as a 40-ft. biplane of the same pattern weighing 2000 lb. But this is not so.

Before an apparatus reaches its least gliding angle it must, of course, have reached its own inherent gliding speed, whether that speed be imparted to it artificially by catapult or other mechanical means, or as the result of a corresponding loss of height. In my experiments I have always resorted to the latter method by dropping the models mostly from kites, height and time being measured. From numerous tests comparing closely with the present case, I can say with certainty that a model biplane, 5 ft. by 10½ in., of medium camber and weighing 31 lb., when released from the kite, dives quite vertically at first, until it reaches its normal gliding speed—92 miles in this case—when it begins and continues to glide at that speed at from 45 deg. to 60 deg. from the vertical, namely, an angle of 1:1 to 1:2 at the very best. The length of the vertical dive corresponds very closely with the ordinary law of $\frac{V^2}{2g}$, in this case about 250 feet. This behaviour of the model presupposes, of course, that it is correctly balanced for its own speed, otherwise that speed may be either exceeded or never reached, with corresponding erratic results, such as a straight dive to the ground or a series of broken dives, deep undulations, &c.

On the other hand, a 40-ft. biplane of the same pattern and proportions, having, namely, $2 \times 40 \times 7 = 560$ sq. ft. of total surface, and weighing 2000 lb., glides automatically, when at the least gliding angle, at 46 miles reckoned along the line of flight, and if of good design should easily reach 1:7. Mr. Lanchester will not find a 40-ft. biplane, 7 ft. wide, with medium camber, and weighing 2000 lb., which can be made to glide at its least gliding angle at anything else than 46 miles within measurable accuracy.

The 5-ft. model, in order to glide at 46 miles, has to weigh 7 lb. 13 oz., more or less resistance in it affecting the gliding angle only, not the gliding speed. Even thus loaded, the model will not do better than 1:5 or 1:6. To glide at 60 miles the 40-ft. × 7-ft. biplane would have to weigh 3380 lb., and the 5 ft. × 10½ in. 13 lb. 4 oz.

This controversy is concerned exclusively with gliding, namely, with that important part of flying which is supplied automatically by gravity unaided, in the shape of a definite normal speed and of a definite amount of lift, generally expressed in terms of the gliding angle. The almost microscopic models to which Mr. Lanchester refers cannot give a basis of comparison, because in these, as in insect flight, viscosity interferes seriously with the action of gravity. But this is of minor consequence. My main query is as to the explanation of the discrepancy revealed by the above comparison between the relative gliding power of a small and a large apparatus of the same pattern.

I fully admit that air resistance is directly proportional to surface, but we know that in gliding and in aeroplane flight by far the greater portion of the lift arises not from pressure, but from suction, and very little is known as yet in regard to the exact origin and properties of that suction.

Mr. Lanchester refers to the excellent work done by the N.P.L., but as far as gliding is concerned, laboratory tests are bound to be misleading, because they miss the most essential factor of gliding, namely, the absence of an external fulcrum, which absence causes a glider to be an ordinary falling body following the path of least resistance, and thus brings into operation some complex laws, the effect of which can only be detected in free flight.

For further explanations on this subject, I will ask Mr. Lanchester to peruse a paper I have prepared, and a few copies of which will be available for private circulation in the course of a few days.

I am, yours faithfully,

JOSÉ WEISS.

Houghton House, Houghton, near Arundel, Sussex, May 1, 1916.

THE MUNITION WORKERS' HAND-BOOK.—We have received a copy of this hand-book, which has been compiled as a guide for persons taking up munition work by Mr. Ernest Pull, A.M.I.Mech.E., R.N.R., M.I.M.E. It is issued at the price of 2s. 6d. net by Messrs. Crosby Lockwood and Son, 7, Stationers' Hall Court, Ludgate Hill, E.C. It opens with useful mathematical data, and explains briefly the manufacture of iron and steel; particulars are also given concerning the properties of other metals. Special chapters deal with the heat treatment of various steels, the common workshop tools, lathe-work, screw-cutting, shell-turning, &c. It will prove a useful companion to many now engaged in the workshops throughout the kingdom.

ROYAL INSTITUTION.—The Annual Meeting of the Members of the Royal Institution was held on Monday afternoon (May 1), the Duke of Northumberland, K.G., President, in the Chair. The Annual Report of the Committee of Visitors for the year 1915, testifying to the continued prosperity and efficient management of the Institution, was read and adopted. The Report of the Davy Faraday Research Laboratory Committee was read. Fifteen new Members were elected in 1915. Sixty-two lectures and nineteen evening discourses were delivered in 1915. The books and pamphlets presented amounted to about 276 volumes, making with 527 volumes (including periodicals bound) purchased by the Managers, a total of 803 volumes added to the Library in the year. Thanks were voted to the President, Treasurer, and Secretary, to the Committees of Managers and Visitors, and to the Professors, for their valuable services to the Institution during the past year. The following gentlemen were unanimously elected as officers for the ensuing year: President—The Duke of Northumberland; Treasurer—Sir James Crichton-Browne; Secretary—Col. Edmond H. Hills; Managers—Sir Thomas Barlow, Bart., Sir William Phipson Beale, Bart., Dr. Horace T. Brown, Sir James Mackenzie Davidson, The Right Hon. Lord Grenfell, Mr. Charles Hawksley, Col. Sir Frederick Nathan; The Hon. Richard C. Parsons, Sir James Reid, Bart., Sir Napier Shaw, Mr. Alexander Siemens, Mr. Silvanus P. Thompson, The Right Hon. Lord Wrenbury, Sir Alfred F. Yarrow, Bart., The Hon. Sir Robert Younger. Visitors—Mr. Horatio Ballantyne, Mr. Sidney George Brown, Mr. John F. W. Deacon, Mr. William Duddell, Lieut.-Col. Henry E. Gaulter, Dr. J. Dundas Grant, Mr. John W. Jarvis, Mr. H. R. Kempe, Mr. Francis Legge, Mr. Ernest R. Moon, Mr. Henry G. Plimmer, Sir William Wyndham Portal, Bart., Mr. Alfred W. Porter, Mr. Hugh Munro Ross, Mr. Joseph Shaw.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, April 19, 1916.

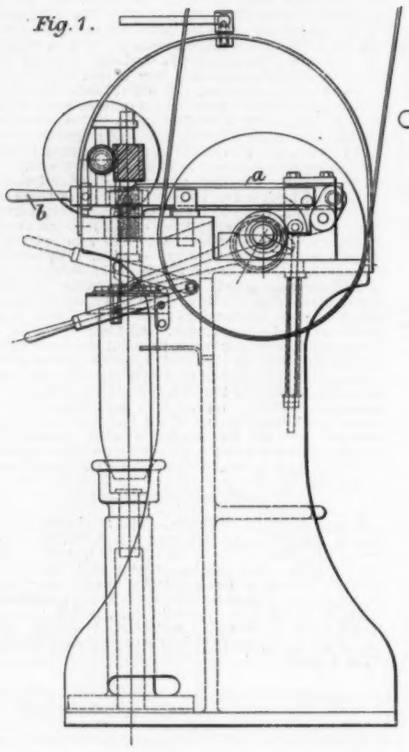
ALL steel companies are pushing deliveries to the limit of their ability. The company that can make satisfactory deliveries can make their own prices. Everything is working on a high tension. Steel rail orders for the week amount to 375,000 tons, including the phenomenal Pennsylvania steel order for 205,000 tons for next year's delivery at 35 dols. a ton for open hearth and 33 dols. a ton Bessemer. The advance in steel rails of 5 dols. a ton affects all rail deliveries after May 1 next. This increase created some excitement. All other kinds of rolled steel are selling around 50 dols. Rails ordered since March 1 are approximately 1,500,000 tons. There are large inquiries from abroad for pig iron and a number of large local concerns are also in the market; we may therefore look for another advance in crude iron, especially basic and Bessemer. The high prices for structural material are holding back a few large contracts, but there is no escape in sight. Plate mills are booked six to eight months ahead and there is an abundance of new business awaiting acceptance. Large orders have just been placed for bridge material and more are coming. The Southern Railway has just ordered 92 all-steel coaches, and the demand for tank cars is taxing the capacity of builders. Canada wants 40,000 tons of basic and Bessemer pig, and France is in the market for 30,000 tons, which is a small part of its total requirements. All kinds of furnace and mill products are in most urgent request and to all outward appearances both foreign and domestic consumers will be obliged to pay higher prices for all future deliveries. The unfilled orders of the United States Steel Corporation approach 1,000,000 tons. The general tone of the market is excited because of the feeling prevailing that material may not be obtainable when wanted. The manufacturers are loth to extend their present obligations, but do not seem to be able to overcome the pressure made upon them.

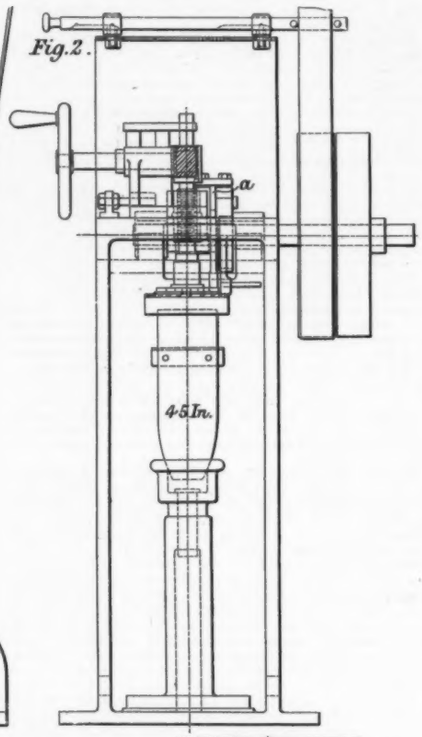
AUSTRO-HUNGARIAN STEEL.—The steel production of Austria and Hungary last year was 2,686,226 tons, as compared with 2,190,759 tons in 1914, and 2,682,619 tons in 1913. Last year's output may be analysed as follows: Bessemer steel, 241,690 tons; open-hearth steel ingots and castings, 2,370,947 tons; puddling iron and steel, 23,543 tons; crucible steel, 26,151 tons; and electric steel, 23,895 tons. In last year's output Austria figured for 1,978,802 tons, and Hungary and Bosnia for 707,424 tons.

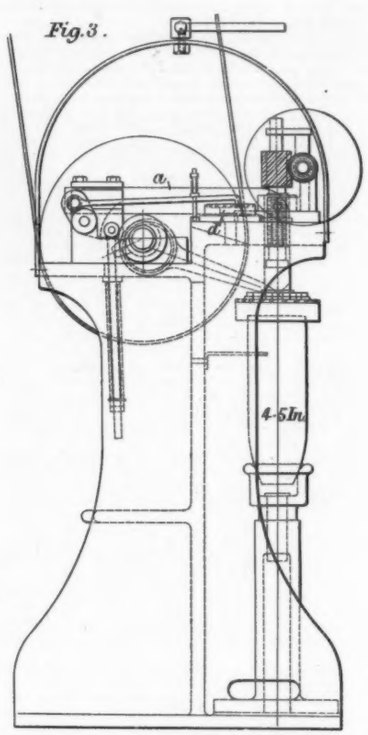
ROYAL WORCESTER LABORATORY WARE.—We have received from the Worcester Royal Porcelain Co., Limited, of Worcester, some samples of porcelain crucibles, evaporating dishes, and boats of their manufacture, together with a copy of a report on some tests of this ware, carried out at the National Physical Laboratory. The dishes, &c., were tested, in comparison with similar vessels of Royal Berlin make, to ascertain the relative effects of chemical reagents, the behaviour of the glaze at high temperatures, the constancy of the weight of the dishes, and their resistance to sudden changes of temperature. The vessels were first subjected for four hours to the action of strong sulphuric acid at its boiling point, and also to the action of 10 per cent. solutions of caustic soda and sodium carbonate, both at a temperature of from 90 deg. to 100 deg. Cent. With the alkalies the minute losses in weight determined for the Worcester ware were in both cases less than for the Berlin ware, while with the acid the Worcester ware showed a very slight increase in weight as compared with a slight loss in weight with the Berlin ware. The amount, however, was so minute as to be quite negligible. To test the behaviour of the glaze at high temperatures a few broken fragments of a dish were placed in another dish of the same kind, and heated for four hours in a gas muffle at a temperature of 1000 deg. Cent. This very severe test was found to affect both dishes, the broken fragments adhering to the sides of the dishes, though they could be broken away with the fingers in both cases. With the Berlin dishes considerable portions of the glaze were broken away with the fragments, and the ware was found to be distinctly discoloured; the surface was also considerably dulled. With the Worcester ware, on the other hand, the injury to the glaze was much less marked, no discoloration was found, and neither was the brightness of the glaze appreciably dimmed, so that, in this respect, the Worcester ware was shown to be superior to the Berlin ware. The loss of weight of the Worcester ware was also found to be entirely satisfactory, as, after heating a dish weighing 22 grammes for one and a half hours in a muffle at 850 deg. Cent., the loss measured was only 0.0002 gramme, which would be within the limits of experimental error. The resistance to sudden changes of temperature was tested by plunging dishes heated to temperatures ranging from 150 deg. to 230 deg. Cent. into cold water. Both makes withstood these tests without cracking, but on slowly re-heating the Worcester dish, which had been previously cooled from the highest temperature, the dish cracked, whereas the Berlin dish remained intact; this treatment is, however, much more severe than would be likely to occur in practice. Both makes satisfactorily withstood a rather more practical test, in which the dishes were removed from a muffle at 850 deg. Cent. with a pair of heavy iron tongs, and placed on a cold stone bench to cool. The conclusion is that Royal Worcester laboratory ware, as far as can be determined by short-period tests, is as good as the best ware hitherto employed. It is, however, being kept under observation, and a report as to its behaviour in long-continued use will be issued later. The ware, in standard forms and sizes, can be obtained from the leading dealers in chemical apparatus.

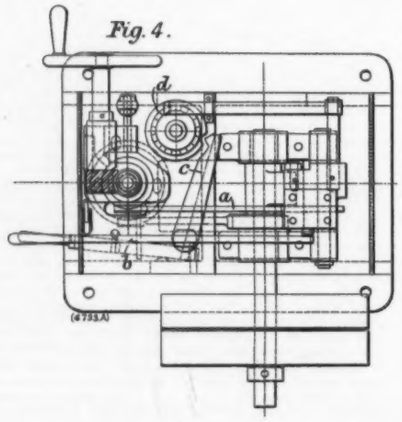
STAMPING-MACHINE FOR MARKING SHELLS.

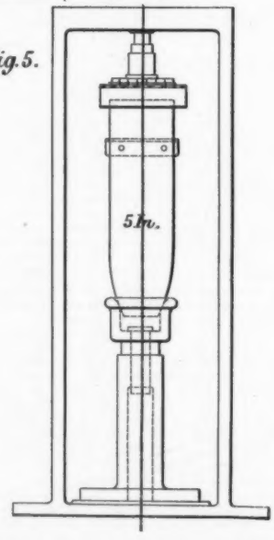
CONSTRUCTED BY MESSRS. J. AND H. McLAREN, ENGINEERS, LEEDS.

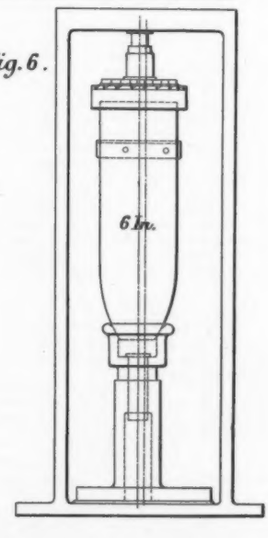












IN a recent article* describing a series of chucks and other tools designed and manufactured by Messrs. J. and H. McLaren, of Leeds, for use in connection with shell-making, we mentioned that the firm's other products of this class included a machine for stamping letters and numbers on the bases of shells. We are now able to reproduce, on this and the opposite page, a photograph and drawings of the latest design of this machine, which, the makers claim, effects a very considerable saving in the time required for the operation of stamping.

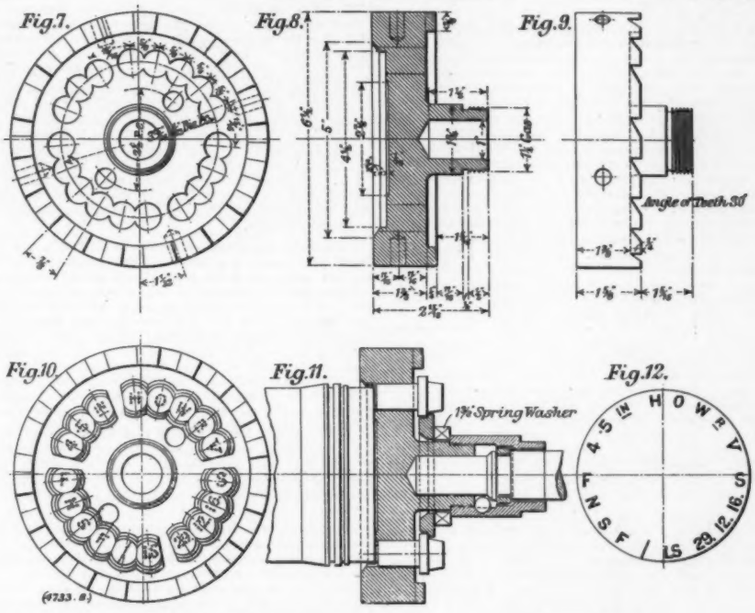
The arrangement of the machine is best illustrated in Figs. 1 to 4, on this page, and its general appearance is shown in the photographic illustration, Fig. 13, on the next page. As will be seen, the shell is placed in a vertical inverted position, with its nose in a cup, supported by a column attached to the base of the machine. The base of the shell fits into a cap made of case-hardened mild steel, which carries near its periphery a number of engraved stamps, and is rotated, together with the shell, so that each of the stamps in succession receives a blow from a hammer, and thus makes an impression on the base of the shell. The machine illustrated is capable of dealing with shells of 4.5 in. to 6 in. calibre, and the only modifications necessary to accommodate the different sizes can be seen by comparing Figs. 2, 5 and 6. The stamp-holder used must, of course, be made to fit the base of the shell in each case, and the height of the column supporting the cup for the nose of the shell must be made suitable for the different lengths. It is also necessary to move the supports a little to the left for the sizes larger than 4.5 in. in order to bring the stamps exactly under the hammer.

It will be more convenient if we describe the design of the stamp-holder before dealing in detail with the machine itself. Referring to Figs. 1, 2 and 3, it will be seen that the stamp-holder is carried by a vertical screwed spindle, on the upper end of which is mounted a spiral gear, which engages with another gear carried by a horizontal shaft. This shaft can be turned by a hand-wheel on the left-hand side of the machine, for the purpose of screwing the stamp-holder down on to the base of the shell when the latter has been placed in position. Detailed drawings of the body of the holder are reproduced in Figs. 7, 8, and 9, on the next page, while Figs. 10 and 11 show all the parts assembled, and Fig. 12 shows the base of a shell after it has been marked by the machine. The body of the holder is drilled with holes, which break into each other, as shown in Fig. 7, and the stamps are made to fit easily into these holes. The stamps, which are made of hardened tool steel, are all bevelled on both sides of the shank, as shown in Fig. 10, to lines radiating from the centre of the holder, and, as the stamps are all in contact on these bevelled faces, no rotary movement is possible, though they are quite free to move vertically. They are, however, prevented from falling out of the holder when the shell is removed by flanges formed on the shanks, as shown in Fig. 11. and this illustration also shows a guard-ring, which is pressed downwards by a

* See page 265 *ante*.

STAMPING-MACHINE FOR MARKING SHELLS.

CONSTRUCTED BY MESSRS. J. AND H. McLAREN, ENGINEERS, LEEDS.



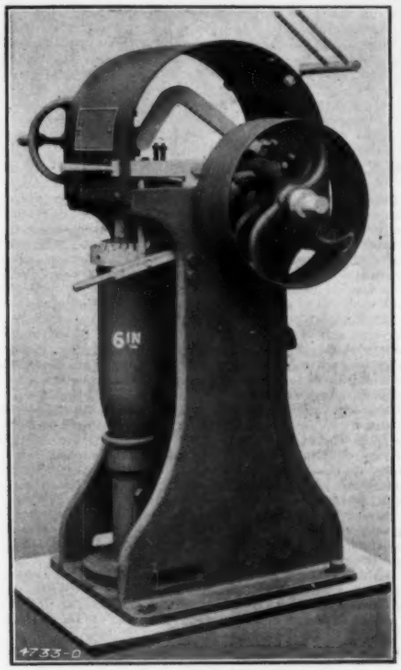
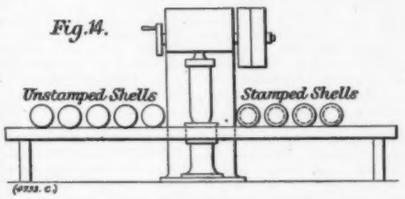


FIG. 13.

spring-washer on to the flanges of the stamps, so as to keep the latter in contact with the end of the shell when the holder is screwed down. It need hardly be mentioned that Fig. 11 has been drawn with the axis of the shell horizontal instead of vertical merely to save space, and the same remark also applies to Figs. 8 and 9. On the upper surface of the holder, near its periphery, is cut a ratchet, the teeth of which, it should be noticed, vary in pitch to correspond with the spacing of the stamps. The rotation of the stamp-holder and shell is effected by means of a pawl, driven by an eccentric on the main shaft of the machine, and engaging with the teeth of the ratchet, the travel of the pawl being sufficient to cover the longest pitch of the ratchet teeth, but not sufficient to cover two teeth of the smallest pitch. The result of this arrangement, which is best shown in Figs. 1 and 3, is that the shell and stamp-holder are always turned through the angle necessary to bring the stamps exactly under the hammer, since, although there is a considerable amount of lost motion when the pawl is working on teeth of small pitch, the movement always finishes at the same place—viz., at the end of the out-stroke of the pawl.

The hammer shaft, which is lettered *a* in Figs. 1 to 4, is bent at right angles near its front end, and is mounted in a trunnion-block pivoted at the back of the machine, the shaft being fixed to the block by a clamping plate and bolts, so that it can be adjusted to strike truly on the stamps. The hammer itself and the method of mounting it are shown most clearly in Fig. 13. A cam mounted on the main shaft, and shown dotted in Figs. 1, 3, and 4, comes into contact with the bottom of the trunnion-block, and raises the hammer against the action of a spring shown dotted in Figs. 1 and 3. As soon as the cam has turned clear of the block, the hammer is forced sharply down by the spring, so that its end strikes one of the stamps, and by adjusting the tension on the spring, the blow can be regulated to give the required impression. The hammer, cam, and the eccentric operating the pawl, are so arranged that the hammer falls during the in-stroke of the pawl, while the stamp-holder and shell are stationary, and the rotation of the latter is effected while the hammer is lifted clear of the stamps. The action continues until the shell has completed a whole revolution, and each stamp has received a blow from the hammer, after which the latter is put out of action by an ingenious piece of mechanism, which is the only detail of the machine remaining to be described.

This device is best shown in Figs. 1, 3, and 4. The long lever, lettered *b* in Figs. 1 and 4, and also visible in Fig. 13, is pivoted at a point near its centre in such a manner that it is capable of moving through a small angle in both the horizontal and vertical planes. A small spring-buffer, shown in Fig. 4, tends to turn the lever in a counter-clockwise direction into such a position that its end would come under a pin in the side of the hammer trunnion-block when the hammer is



raised to its fullest extent. This would, of course, prevent the hammer from falling, but the horizontal movement of the lever cannot take place unless the V-shaped projection on the arm *c*, in Fig. 4, coincides with a corresponding notch in the periphery of a ratchet-wheel *d*. The ratchet-wheel, which has the same number of teeth as the stamp-holder ratchet, is rotated by a drag-pawl, shown in Fig. 3, operated by the trunnion-block, and is pulled round through the space of one tooth each time the hammer is raised. This goes on until all the stamps have received a blow from the hammer, when the projection at the end of the arm *c* slips into the groove of the ratchet-wheel, and the hammer is retained in the raised position, as explained above. The shell, however, continues to rotate until the pawl, driven by the eccentric on the main shaft, is released by raising a hand-lever clearly shown in Figs. 1 and 13, when the stamped shell can be removed and another one inserted. The hammer is then re-started by moving the lever *b* to the left, but before this can be done, the pawl which rotates the shell must have been lowered into engagement with the ratchet of the stamp-holder. An inspection of Figs. 1 and 13 will show the reason for this, as it will be seen that, when the pawl is lifted away from the ratchet of the stamp-holder, a vertical rod, connected to the lifting lever, is raised on the right-hand side of the lever *b*, thus preventing the latter from being moved. It is, of course, important that the hammer should not be released just as the revolving cam is coming up towards the bottom of the trunnion-block, as the hammer blow would then be delivered on to the cam instead of on to one of the stamps, and one of the letters would be missing from the shell. To prevent this the stop-pin on the trunnion-block is placed in such a position that when the hammer is in the raised position it is lifted slightly at every revolution of the cam, thus raising the stop-pin a short distance above the end of the stop-lever. At this instant the stop-lever can easily be moved to start the hammer, but it cannot be moved at any other part of a revolution, since the stop-pin is under-cut and the end of the lever bevelled off so as to hold the lever in engagement with the pin until the latter is lifted, as explained. In this position the hammer drops clear of the cam, so that the first blow is always of the same magnitude as the others.

It will be seen that the machine is practically proof against careless operation. As first designed the results obtained were largely dependent on the operator, who sometimes set the hammer working without starting the rotating device for the shell, with the result that the whole of the blows fell on one of the stamps. He had also to stop the machine by shifting the belt when the stamping was completed, and this was sometimes done too soon, so that some of the letters were missed. At other times the machine was stopped too late, so that time was wasted and some of the stamps received two blows. These troubles have all been eliminated by the devices above described, so that the machine is now completely automatic in action, and can be operated by quite unskilled persons. A convenient method of feeding the machine, especially suitable for use when stamping heavy shells, is indicated by the sketch reproduced in Fig. 14. A strong plank is supported in a horizontal position, so that its upper surface is just below the level of the cup which holds the nose of the shell. The unstamped shells are placed on one end of the plank, and one of them is rolled along until its nose comes over the cup. It is then raised into a vertical position, with its nose in the cup and its body resting against a cradle, shown in Figs. 1 and 3, the stamp-holder being then screwed down and the stamping proceeded with. When completed, the shell is taken out of the machine and rolled along to the other end of the plank, from which a batch can be removed at intervals.

CANADIAN MINERALS.—The value of the mineral production of Canada last year was 138,513,000 dols., as compared with 128,863,000 dols. in 1914 and 145,634,000 dols. in 1913. The sharp contraction observable in the total for 1914, and from which there was a partial recovery last year, was due, of course, to the great European war. The recovery of 1915 was, however, also due, to some extent, to the war, which, after the first shock, produced an increased demand for metals. Ontario contributed 61,800,000 dols. to the value of Canada's mineral production in 1915, or more than twice the amount standing to the credit of British Columbia, and three times as much as the contribution of Nova Scotia. Ontario led in 1915 in gold and silver production, while it has a monopoly of Canadian nickel production. Coal is the principal contributor to the mineral output of Nova Scotia. The value of the metals produced in Canada in 1915 was 77,046,000 dols., an increase of 18,000,000 dols. over 1914. The value of the non-metallic minerals produced in Canada last year was 42,755,000 dols. Among the principal non-metallic minerals were coal, natural gas, asbestos, gypsum, pyrites, salt and petroleum. The natural gas production showed a decrease in 1915, indicating that sources which have been heavily tapped of late years are beginning to give out. The production of petroleum also declined last year.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-iron Market.—The recent order in Council prohibiting speculation in pig-iron and the still more recent embargo upon its export has played havoc with the Glasgow pig-iron warrant market. For many years one of the most important features of local industry, it seems almost to have sunk into comparative insignificance, and it is expected that by the end of this month the total store of pig-iron will have been completely cleared out. Last Wednesday afternoon buyers offered 82s. 6d. per ton for Cleveland warrants, but without effect, and similar conditions prevailed on Thursday. No business was done on Friday either, sellers refusing to deal at 82s. 6d. Owing to the Bank Holiday on Monday the market was closed, but the reopening yesterday showed no improvement, matters being just on the same level as last week.

Scotch Steel Trade.—Perhaps nothing could exceed the activity in the local steel-making establishments, the pressure for finished steel of every description, and notably for shell bars, continuing on a most extensive scale. If the efforts which are being made to regard mercantile shipbuilding as "war work" prove successful, this would mean a considerable increase of business, and that of a more varied character for steel-makers generally, and particularly for those whose chief output for some months past has been shell bars. The Government's demands, both directly and indirectly, are insatiable, and private consumers are finding an increasing difficulty in obtaining supplies of certain much-required sections. Indeed, it is quite an open secret that despite all the efforts being made it seems almost impossible for producers to keep pace with the demands of our own and the Allied Governments. This being so, there is little chance of many export licences being granted meantime, so that the prospects of the oversea trade are none too brilliant. It is increasing activity all the time. Sectional material, rolled from shell-discarded steel, is now available for ordinary purposes, both home and export, in considerable quantity. In most branches of the steel trade maximum prices have now been fixed, and those which have not yet been "roped in," will probably be so ere very long. While export rates continue very firm, for home delivery boiler-plates still run about 14*l.* 10s. per ton; ship-plates, 13*l.* 7s. 6d. or up to 13*l.* 15s.; and angles, 13*l.* 15s. or 14*l.*, all less the usual 2½ per cent. discount.

Malleable Iron Market.—In the malleable iron trade, there is little fresh development and almost nothing to record other than the ceaseless activity prevailing at all works where Government contracts are being put through. Iron bars are in great demand, for the export trade, and prices have again stiffened, it being doubtful if any business is being done under 13*l.* 17s. 6d. net. f.o.b. For the best quality "Crown" bars, 14*l.* 7s. 6d., less 5 per cent., has been paid for prompt home delivery.

Scotch Pig-Iron.—The home demand for Scotch pig-iron is keeping makers well employed, but just at the moment export shows a decided falling off, due, naturally, to the latest prohibition order, which demands a Government licence before any shipment can take place. Both hematite and foundry grades come under this restriction. At the various steel works, however, there is an exceptionally heavy local demand for hematite, as well as for foundry and forge iron, and in consequence of the restriction a much larger quantity is available. When the order comes fully into force it is confidently expected that certain changes will take place, but meantime these can only be hinted at. Prices of makers (No. 1) iron are practically on the same level as last week, the current quotations being as follow:—Clyde, Calder, Summerlee, and Langloan, 130s. per ton; Gartsherrie, 131s. 6d. (all shipped at Glasgow); Eglinton, 126s. 6d.; and Glengarnock, 130s. (both at Ardrossan); Dalmellington, 126s. 6d. (at Ayr); and Shotts, 130s. (at Leith).

Scotch Shipbuilding During April.—While there is a growing expectation that shipbuilders will shortly be permitted a freer hand in the construction of mercantile vessels, as matters stand in the meantime Naval work, both building and repairing, takes precedence in every yard of any importance whatever. The consequence is that only four merchant vessels have been launched in Scotland during the month of April. These four vessels totalled a tonnage of 15,171 tons, two representing 7557 tons being launched on the Clyde, one of 214 tons on the Forth, and one of 7400 tons on the Tay. For the four months just ended the total tonnage for the Clyde figures out at 24,513 tons for seven mercantile vessels, which, of course, can in no way be compared to normal years, in which Naval and Military work is also included. In the same period of last year the output of purely merchant work amounted to 114,183 tons. Despite persistent rumours about new orders having been placed, very little seems to have been definitely fixed. The Federal Steam Navigation Company of London, however, has commissioned two steamers from Messrs. Wm. Hamilton and Co., Port Glasgow, and one from Messrs. Napier and Miller, Old Kilpatrick. From the following figures will be seen the total mercantile output since the beginning of the year:—Clyde, 7 vessels, 24,513 tonnage; Forth, 4 vessels, 2777 tonnage; Tay, 1 vessel, 7400 tonnage; Dee, 10 vessels, 1342 tonnage.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—Collieries are working with marked regularity now and supplies are coming forward with greater frequency and in larger quantities. A general scarcity still prevails, for the aftermath of the pit holidays is the depletion of any reserve stocks that works had on hand. Munition establishments are now anxious for supplies for the daily running, but, in addition, are constantly "nibbling" for any surplus to form the nucleus of future reserves. Some criticism has been directed at the workings of the local committee appointed by the Board of Trade and the Ministry of Munitions, which is exercising an oversight over the even distribution of fuel for industrial purposes. It is alleged the committee is comparatively inactive, but on the other hand it is pointed out that the committee has charge of a large area, comprising more than 40 collieries, including the principal collieries in the South Yorkshire district, and it is suffering constant reduction of its clerical staff by the demands of the military. The general inquiry for manufacturing fuel of all descriptions is on a large scale and collieries have numerous orders on their books for contract account. There is nothing available on the open market. For shipment, the tonnage is again on a smaller level, even in the case of French requirements, and this is said to be due to the expanding needs of local works and the consequent stricter regulation of the export licences. All fuel for foreign ports is quoted fully 5s. to 6s. above the home market prices. Gas fuel barely satisfies contract accounts, and it is stated that the Sheffield Gas Company is in the market for the supply of half a million tons of gas, house, and small coal. Slacks are a short supply. The position in the house coal section has taken an unexpected turn for the worse, for there has been a big run on the small stocks held by agents and merchants, and many households have, for a time at any rate, been without coal. Quotations:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best silkstone, 18s. 6d. to 19s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. 6d. to 16s. 6d.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 12s. to 13s.; seconds, 11s. to 12s.; smalls, 8s. to 9s.

Iron and Steel.—Steel workshops are now thoroughly settled down after the holidays and the daily output is equal to that of the earlier part of the year. The only important alteration is that whereas Allied Governments were only among the many customers for Sheffield steel, they are to-day taking almost the entire output and it is expected that in the near future Sheffield steel will be almost exclusively required for the purposes of war. There is a general briskness all round. Tool steel is in large demand, both high speed and the carbon varieties, and the supplies are not adequate to meet the requirements of Allied countries. In the other lines there is a continued scarcity of raw and semi-finished material. Swedish supplies are only coming slowly to hand and manufacturers have perforce to make a big hole in the stocks they have in reserve. Billets were held in substantial quantities some time ago, but are now dwindling. The iron and steel market undergoes little alteration and there are no official changes to record in the prices this week. Dealers are demanding the maximum in all cases. Buying has fallen off considerably in the iron market, except for the large supplies of hematite secured on behalf of munition undertakings. Foundry iron meets only a meagre demand, the forge quality being much more sought after. The Sheffield Cutlers' Company are taking steps with a view to getting the Government to moderate the recent proclamation prohibiting the export of steel or steel products of all descriptions to any country. The Cutlers' Company have long been supervising the export steel trade and are held to have saved the situation by the promptitude with which they have issued export certificates. Instead of having to wait three weeks or thereabouts for a Government licence, makers have obtained a certificate from the Cutlers' Company stating that the steel ordered for shipment did not contain alloys, and profitable overseas business has been secured in consequence. The rigid adherence to the proclamation ends this well regulated avenue of trade and the Cutlers' Company are eager to secure the necessary authority to continue. Much interest is being displayed in the matter. In goods which are necessary for munition production, viz., files, saws, twist-drills, and small tools for engineers, a boom is just now being experienced and manufacturers are finding trade very remunerative on account of the excellent prices paid. In certain cases users say the cost is prohibitive, but at the same time there is a ready sale for all production. Stainless steel cutlery is becoming increasingly popular and not only British but overseas agents are asking for unusually heavy deliveries. The output is larger than at any previous time, but it is nevertheless hopelessly insufficient. A consequence has been a depreciation in the value placed on several electro-plated articles. The foreign and colonial mail furnishes excellent business weekly and the latest indents to arrive are for steel, tools, springs, files, bolts, and saws.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

Distribution of Pig Iron.—The Local Committee appointed to regulate, the distribution of pig iron are unlikely to release any iron for export until the supply is such as more than to meet home needs, and consequently exporters are making no effort to do business with customers abroad, fully realising that it is hopeless to apply at present for export licences. Even for France permits are very sparingly issued, so scarce has iron become. Consumers in France are pressing for deliveries under contracts already made. Shipments to that country go steadily on, but they fall considerably short of what could be wished by our ally.

The Cleveland Iron Trade.—Business in Cleveland pig iron is very quiet. It is difficult definitely to fix quotations for export. Generally the recognised nominal rate for No. 3 is 90s., but 91s., 92s. and higher figures have also been named. No. 1 is 94s. and upward; No. 4 foundry is quoted from 89s., and No. 4 forge from 88s. For home consumption No. 3 remains at the fixed maximum of 82s. 6d., and that price is also named for foundry and forge iron, while No. 1 for home use is put at 86s.

Hematite Iron.—There is very little new to report concerning the East Coast hematite branch of the staple industry. Producers have disposed of their output for some months ahead, and many of them do not care to enter into further contracts. Thus business is almost at a standstill. Home supplies are regulated by the committee at the fixed maximum of 122s. 6d. for mixed Nos. Shipments to our Allies are very rigidly supervised, and no permits for deliveries to neutral countries are being issued. The export quotation for mixed Nos. remains at 140s.

Stocks of Pig Iron.—Practically the only free iron for prompt business is a portion of that in the public warrant stores here. A good deal of the store iron is already earmarked for delivery. At the end of April the quantity of iron in the stores stood at 40,405 tons, of which 37,945 tons were No. 3 Cleveland, and 2460 tons other qualities of Cleveland iron, deliverable as standard. During last month 16,987 tons of No. 3 were taken from the stores, and 82 tons of standard iron were added, giving a net decrease for the month of 16,905 tons. There are warrants in circulation for 24,600 tons: 23,000 tons of No. 3, and 1600 tons of standard iron.

Coke.—Coke keeps steady and firm. Local needs are rather heavy, and adequate deliveries are being made to users in this district. Prices do not alter. Average blastfurnace qualities are 28s. at the ovens, and descriptions low in phosphorus are quoted up to 30s. 6d. at the ovens.

Foreign Ore.—Quietness characterises the foreign ore trade so far as new business is concerned, but large supplies are coming to hand against contracts. The action of the Government is steadily bringing freights down, but in the ordinary way in the open market up to 20s. has still to be paid Bilbao-Middlesbrough, and this, with the f.o.b. price of 50 per cent. Rubio at 17s. 6d., makes the ex-ship fees figure 37s. 6d; but consumers buying to manufacture iron for home use are able to arrange, through the Government, steamers Bilbao-Middlesbrough at 17s., which makes the ex-ship Tees price of best Rubio to them 34s. 6d. Imports of foreign ore to the Tees for the first three days of the month amount to no less than 24,580 tons.

Ironstone Miners Wages Advanced.—The Cleveland Ironstone Miners have been conceded an advance of 10 per cent. in wages, raising the rate to 60 per cent. above the standard of 1879. Thus, Cleveland miners' wages become 9 per cent. higher than those of local blast-furnacemen. Both miners and furnacemen's wages are regulated by the ascertained price of Cleveland pig iron. The latter, however, have a war bonus, which the miners have not.

Manufactured Iron and Steel.—Nothing new of moment is ascertainable concerning the various branches of the finished iron and steel industries. Manufacturers continue working at full pressure on Government work, with the result that ordinary commercial business is still largely neglected. Principal market quotations stand:—Common iron bars, 13*l.* 15s.; best bars, 14*l.* 2s. 6d.; double best bars, 14*l.* 10s.; treble best bars, 14*l.* 17s. 6d.; packing-iron (parallel), 10*l.*; packing iron (tapered), 11*l.* 15s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 15s.; iron ship-rivets (¾-in.diameter), 16*l.* 10s.; iron ship-rivets (⅝-in. diameter), 17*l.* 10s.; steel bars (no test), 14*l.* 10s.; steel ship-plates, 11*l.* 10s.; steel ship-angles, 11*l.* 2s. 6d.; steel ship-rivets (¾-in. diameter), 18*l.* 10s.; steel joists, 11*l.* 2s. 6d., and heavy steel rails, 10*l.* 17s. 6d., all net.

Iron and Steel Shipments.—The total shipments of iron and steel from the port of Middlesbrough last month amounted to 97,182 tons, as compared with 94,951 tons for the previous month. The total despatches for April last year were 63,359 tons, and for April, 1914, 192,704 tons. Of the 61,815 tons of pig iron loaded last month, 60,309 tons went abroad, and 1506 tons coastwise. For the previous month the shipments of pig amounted to 62,010 tons. There was thus last month a decrease of only 195 tons, notwithstanding the embargo on exports. France was the largest receiver, taking 34,624 tons, or 2779 tons more than in March. Italy last month took 6500 tons, or 3087 tons less than in March. Sweden and Norway imported 9043 tons, an increase of 1151 tons, and Japan was a customer to the extent of 3907 tons, or 1633 tons more than in the preceding month. April shipments of manufactured iron and steel reached 35,367 tons, as compared with 32,941 tons for March. The principal importers were: France, 22,402 tons, or 943 tons more than in March; Japan, 4701 tons, or 1504 tons more than in March; and India and Ceylon, 2885 tons, or 210 tons more than in March.

AMMUNITION WORKS IN GERMANY.—In the course of a lecture on the Chief Tasks of German Ironmasters During the War, delivered by Dr. W. Petersen, before the annual meeting of the Verein Deutscher Eisenhüttenleute, held in Düsseldorf, in March last, the lecturer remarked that there was no dearth of raw materials nor of ferrosilicon, manganese, copper-sulphate, magnesite, &c.; he did not make any mention of nickel, however. Only eight works had been making drawn projectiles before the war, at present 90 works were engaged in that particular production.

NOTES FROM THE SOUTH-WEST.

Cardiff.—The South Wales steam-coal trade has remained in much the same state. Current outputs show a considerable decline, having been reduced by prolonged holidays. The effect of this has been that there has been something like a famine for both large and smalls. Of the coal produced, the authorities have taken everything which has suited their purpose, leaving the markets, to a large extent, bare of supplies for commercial purposes. As much as 55s. per ton is stated to have been realised for coal in a few isolated instances; and with a large number of vessels waiting in dock for supplies there is no prospect of any weakening in values for some time. The best Admiralty large steam coal has been, to some extent, normal; secondary qualities have made 52s. to 53s.; ordinary Western Valleys, 52s. to 52s. 6d.; Monmouthshire Black Veins, 52s. 6d. to 53s.; Eastern Valleys, 49s. to 50s.; best bunker smalls, 30s. to 32s.; and cargo smalls, 22s. to 25s. per ton. In bituminous coal, best households have made 23s. to 24s. at the pits; No. 3 Rhondda large, 52s. to 53s.; smalls, 32s. to 33s.; No. 2 Rhondda large, 44s. to 45s.; and No. 2 smalls, 22s. to 24s. per ton. The latest quotation for patent fuel has been 50s. to 52s. 6d. per ton. Special foundry coke for export has been quoted at 60s. to 65s.; good foundry coke, 55s. to 60s.; and furnace coke, 45s. to 50s. per ton. As regards iron ore, Rubio has made 35s. to 37s. per ton, charges included.

Western Trade Matters.—In consequence of the continuance of the war, the directors of the New Dunderland Company found it impossible to proceed with the installation of the proposed magnetic separation plant, and the company's engineers set to work to design an alternative plant obtainable from British and neutral sources. This alternative system of treatment has now been decided upon, and the necessary orders are being placed for the requisite additional plant and machinery, which is to be capable, in the first instance, of dealing with 500 tons of ore per day. If in practice the process which has been adopted proves satisfactory, the capacity of the plant will be steadily increased to 1500 tons per day. The trade of the Port of Swansea has been severely affected by the war, and the finances of the port have been disturbed. In 1914 the tonnage movement dealt with declined 1,139,600 tons, and last year there was a further decline of 215,200 tons; and tonnage dues declined from 65,300*l.* to 61,300*l.*—The total revenue of the Swansea Harbour Trust from all sources last year was 297,500*l.* in round figures, and the working expenses were 170,600*l.*, leaving a net surplus of 126,900*l.* As, however, charges amount to 170,000*l.* per annum, there was a deficit last year of 43,100*l.*, reduced by sundry other assets to about 1,000*l.*—The Westoe Hall, built at South Shields in 1914, and carrying 7730 tons dead-weight, hitherto owned by the Nicholl Steamships, Limited, Cardiff, has been sold to British buyers for 130,000*l.*—The Albert Hall, built at Sunderland in 1914, and carrying 8250 tons dead-weight, hitherto owned by the Nicholl Steamships, Limited, has been sold to British buyers for £150,000.—Another illustration of the highly profitable character of modern shipping business is afforded by the annual report of the Temple Shipping Company, Cardiff. The company owns five steamers, with a total dead-weight capacity of 27,000 tons, and the profit realised in 10¼ months ended March 31 was 154,503*l.*, as compared with 18,755*l.* in the previous twelve months. In the course of the last financial year the paid-up capital was increased from 80,000*l.* to 100,000*l.* The profits for 1912 are returned at 8,524*l.*; for 1913, at 25,907*l.*; for 1914, at 16,290*l.*; for 1915, at 18,755*l.*; and for 1915–16 at 154,803*l.* The book value of the company's fleet stands at 100,600*l.*, the amount of the paid-up capital of the undertaking.—The National Chamber of Trade has been holding its annual meeting at Cardiff. The Lecture Hall of the South Wales Institute of Engineers was placed at the disposal of the Chamber. Mr. F. C. Walsham, of Huddersfield, who presided, called attention to the exemption of co-operative societies from taxation. He said he had recently been reading the reports of two large co-operative wholesale societies, and he found that not only had their capital grown enormously, but that their sales, profits, and reserve funds had also reached huge totals. It was not difficult to appreciate the amount of taxation which ought to have been paid by these people.

THE BRITISH CHAMBER OF COMMERCE FOR ITALY.—The headquarters of the chamber have been removed to 7, Via Carlo Felice, Genoa, where sample show-rooms for British goods are being organised.

THE LATE Mr. HOWARD BUTTERS.—We regret to have to announce the death, which occurred on April 24, at Chagford, Exeter, of Mr. Howard Butters, who was a member of the Institution of Mechanical Engineers since 1910. Mr. Butters was born at Banbury in 1876. He was educated privately and at the Stranrser School, Bournemouth, and the Camberwell Grammar School. He acquired his technical training at Goldsmiths' College, New Cross, and served his apprenticeship, from 1893 to 1897, with Messrs. Woodhouse and Mitchell, Brighouse, Yorks. He was employed as draughtsman by the same firm from 1897 to 1899. From 1899 to 1900 he was employed as engine draughtsman at the Low Moor Iron Works, a position which he then left for New Zealand, where he was occupied for a number of years in railway construction and other work. Mr. Butters was the inventor and patentee of Butters' patent fencing.

THEORY AND PRACTICE IN THE FILTRATION OF WATER.

By WALTER CLEMENCE, Member, of Shortlands, Kent.

(*Continued from page* 414.)

Settling-Tanks at Cawnpore.—The question of the advantage or otherwise of utilising the settling-tanks at Cawnpore has received careful consideration since the multiple-filtration plant was completed. As already stated, the water is merely circulated over the surface of the three tanks, and the most that can be expected is that a certain quantity of the coarser silt will be deposited. But a very few grains of fine sand may easily weigh as much as many thousands of the extremely fine particles of silt or clay granules to be found in waters of rivers, like the Ganges, which flow through alluvial plains. A series of observations has been made at Cawnpore (*a*) on the effect of decantation with sulphate of alumina; (*b*) on the elimination of silt effected at each stage in multiple filtration; and (*c*) on the effect of passing the water over the surface of the settling-tanks followed by multiple filtration.

The following are some of the results obtained:—

Effect of Settling-Tanks used as Decanting Basins with Sulphate of Alumina as Coagulant.

	No. 1. July 18, 1912.	No. 2. August 30, 1912.
Raw water	79 parts per 100,000	101 parts per 100,000
After decantation ..	28 " "	32 " "
Percentage reduction	64.55 per cent.	68.31 per cent.

Effect of Multiple Filtration with Raw Water supplied direct to Degrossisseurs. No Chemicals used.

	No. 3. September 4, 1912.		No. 4. November 13, 1912.	
	Parts per 100,000.	Reduction.	Parts per 100,000.	Reduction.
		Per cent.		Per cent.
Raw water ..	121.75	—	37	—
Degrossisseurs 1	46.6	61.72	25	32.43
" 2	31.9	73.79	20	45.94
" 3	21.1	82.66	18	51.35
Pre-filters ..	13.4	88.99	14	62.16
Slow sand filters	15.7	87.10	16	56.75
	No. 5. July 1, 1913.		No. 6. July 15, 1913.	
Raw water ..	58	—	55	—
Degrossisseurs 1	50.5	12.93	27.5	50
" 2	25	56.89	26	52.72
" 3	20	65.51	19	65.45
Pre-filters ..	14	75.86	15	72.72
	No. 7. July 29, 1913.		No. 8. August 12, 1913.	
Raw water ..	180	—	88	—
Degrossisseurs 1	115	36.11	23.5	73.29
" 2	100	44.44	27.5	68.75
" 3	60	66.66	19	78.4
Pre-filters ..	27	85	23	73.86

Effect of Multiple Filtration with Raw Water circulated over Surface of Settling-Tanks before Delivery to Degrossisseurs. No Chemicals used.

—	No. 9. Average of Analyses in June and July, 1914.	
	Parts per 100,000.	Reduction.
		Per cent.
Raw water	72	—
After settling-tank No. 1 ..	45	37.5
" " No. 2 ..	28.5	60.41
" " No. 3 ..	23	68.05
Degrossisseurs 1	22	69.44
" 2	20.5	71.52
" 3	17.5	75.69
Pre-filters	9.6	86.8

Of the above analyses, Nos. 1, 2, and 4 are by Dr. Hanbury Hankin, Government Bacteriologist, Agra; No. 3 is by Dr. S. Rideal, London; Nos. 5 to 8 by Assistant Surgeon Manohar Lal, Cawnpore, and No. 9 by Monsieur P. Bonzel, of Lille, who superintended the arrangements for working the filters from May to August, 1914. The average results in percentage reduction of total solids seem to show that the various methods of treatment of the water antecedent to slow sand filtration may be classed in the following order:—

	Per Cent.
1. Settling-tanks as circulators, degrossiseurs and pre-filters, without chemicals	86.8
2. Degrossisseurs and pre-filters only...	77.66
3. Settling-tanks as circulators and degrossisseurs...	75.69
4. Degrossisseurs only	68.3
5. Settling-tanks as circulators ...	68.05
6. Settling-tanks as decanting basins with sulphate of alumina	66.43

But a careful examination of the above tables will show that the figure for total solids may be misleading unless the nature of the silt is carefully considered. The settling-tanks are certainly more efficient in prolonging the life of the final filters when sulphate of alumina is used, and although the analyses show that a greater weight of silt is removed if the water is first circulated through the settling-tanks, it must be remembered that this may be accounted for by a few large particles which, without the use of settling-tanks, would easily be arrested by the degrossisseurs in multiple filtration.

The great disadvantage attending the use of settling-tanks in any form is that the periodical cleaning of them is frequently neglected. So long as the suspended matters which have been deposited cannot be seen, their presence is forgotten, until an abnormal growth of algæ or diatoms appears on the final filters, developed from the vast accumulation of spores deposited in the settling-tanks. If the water is delivered direct on to the degrossisseurs in multiple filtration, the whole of the silt deposited on the gravel must be cleared away at frequent intervals, and there is no accumulation of solid organic matter in any part of the installation. In tropical countries especially, where the temperature of the water is comparatively high, it seems possible that pathogenic organisms could exist for a considerable time in an accumulation of organic matter at the bottom of a settling-tank, whereas any such accumulation is impossible in a multiple-filtration plant.

The comparative dimensions of the particles of sand in a filter, the interstices between the particles, and the silt and pathogenic organisms removed during the process of filtration, are illustrated by the photomicrographs reproduced on the next page. Of these, Figs. 12 and 13 show the surface of the sand used in the pre-filters and final filters at Cawnpore. Figs. 14 to 17 and Figs. 18 to 21 show particles of silt in the raw water of the Ganges and after each successive stage of purification. These illustrations are from slides prepared from samples of the water taken at Cawnpore on July 8, 1914, when the installation was being worked at its maximum capacity of 7,000,000 gallons per 24 hours. They are intended to show the largest particles which could be found in each preparation, and the number of particles in each photograph is of no value for purposes of comparison. The largest particle of silt in the raw water measures 0.18 mm. at its greatest diameter, while in all the photographs a large number of particles measuring less than 0.001 mm. may be seen. It will readily be understood that the loss of the large particles by decantation will make an enormous difference in a test for "total solids" by evaporation, without affecting the turbidity of the water in any marked degree or reducing the difficulty of effecting complete clarification by filtration.

The photomicrographs, Figs. 12 to 21, on the next page, are by the author, and have been slightly reduced in our illustrations. Pathogenic bacteria photographed on the same scale would be almost invisible. Figs. 22 and 23, therefore, which show *B. Typhosus* and *Sp. Cholera Asiatica*, are more highly magnified, and for purposes of comparison rings are drawn on the photographs of sand, Figs. 12 and 13, the rings roughly representing the space which would be occupied by Figs. 22 and 23 if reduced to the same scale. The author is indebted to Dr. E. J. Spitta for the photographs of bacteria, which are from the original plates used to illustrate "An Atlas of Bacteriology," by Drs. Slater and Spitta, and they are here reproduced by permission of the authors.

On comparing the photographs of sand, Figs. 12 and 13, it will be noted that the red sand in the pre-filters is composed of much coarser grains than that used in the final filters, and it might be supposed that the water would pass more freely through the pre-filters than through the final filters. A careful examination of both sands shows that this is not the case.

The coarse sand is from the Jumna at Kalpi, and it will be seen that the grains are very smooth. The specific gravity of the sand is 2.57 and its proportions in mass are 63.8 per cent. solid to 36.2 per cent. void. The fine sand, Fig. 13, is quartz sand from the bed of the Ganges at Cawnpore. It is very much finer than the sand usually employed in filtration, but the grains are sharp and angular. The specific gravity of this sand is 2.63 and the proportions 58.8 per cent. solid to 41.2 per cent. void. These figures show that a coarse sand does not necessarily allow a more rapid percolation of the water than a fine sand. As the void is divided about equally between the vertical and horizontal interstices, the actual area through which the water can pass downwards in filtration is only about 20 per cent. of the total area of the filter if a sharp sand is used, while it may be considerably less with a smooth sand. In referring to the speed of a filter it is convenient and customary to state the rate in inches per hour at which the water on the filter falls vertically, but the fact that the speed of the water through the sand-bed may be as much as five times that of the water above the sand is sometimes disregarded.

Loss of Head due to Friction through Sand-Bed.—In January, 1911, the author had an opportunity of testing one of the sand filters at Cawnpore in order to ascertain the loss of head absorbed by friction with the very fine sand employed. The filter had been re-sanded to a depth of 2 ft. 6 in. and was then filled with filtered water, which, for the purposes of the test, was run off at varying speeds.

At the normal maximum speed of 50 gallons per sq. ft.

* Paper read before the Institution of Mechanical Engineers, April 14, 1916.

MICROPHOTOGRAPHS ILLUSTRATING PRACTICE IN THE FILTRATION OF WATER.

FIG. 12. COARSE SAND IN PRE-FILTERS.

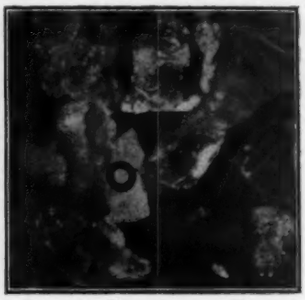


FIG. 13. FINE SAND IN FINAL FILTERS.

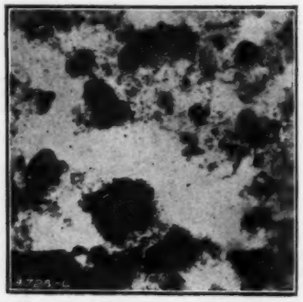


FIG. 14. SILT PARTICLES IN RAW WATER AT INLET TO SETTLING-TANK NO. 1

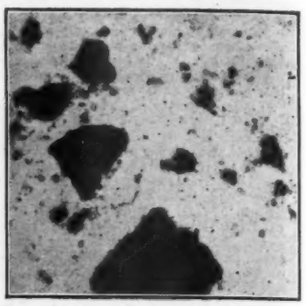


FIG. 15. SILT PARTICLES IN WATER FROM SETTLING-TANK NO. 2.

MAGNIFICATION 80 DIAMETERS

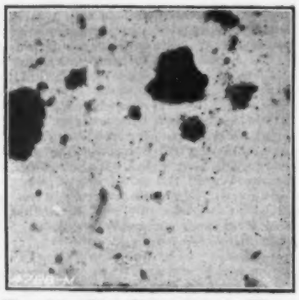


FIG. 16. SILT PARTICLES IN WATER FROM SETTLING-TANK NO. 3.

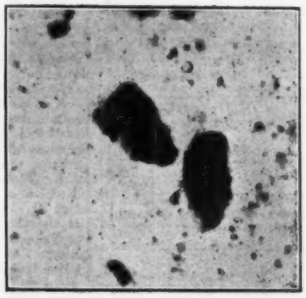


FIG. 17. SILT PARTICLES AT INLET TO MULTIPLE FILTERS.

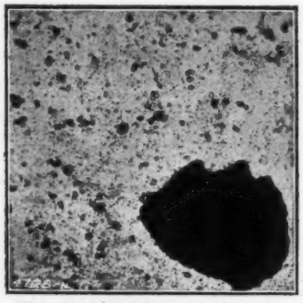


FIG. 18. SILT PARTICLES AFTER DEGROSSISSEUR NO. 1.

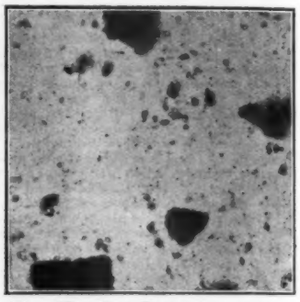


FIG. 19. SILT PARTICLES AFTER DEGROSSISSEUR NO. 2.

MAGNIFICATION 80 DIAMETERS.

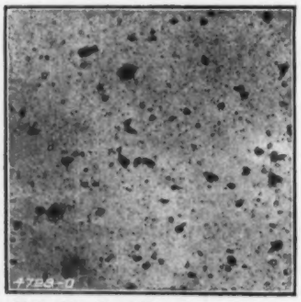


FIG. 20. SILT PARTICLES AFTER DEGROSSISSEUR NO. 3.

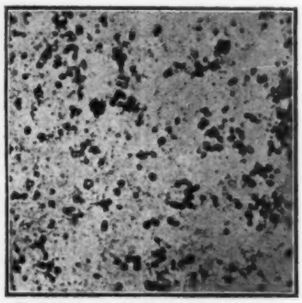


FIG. 21. SILT PARTICLES AFTER PRE-FILTERS.

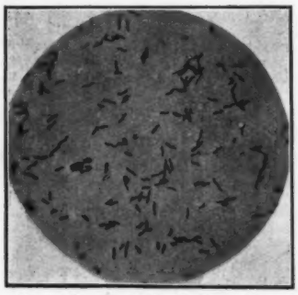


FIG. 22. B. TYPHOSUS. AGAR CULTURE, 48 HOURS' GROWTH.

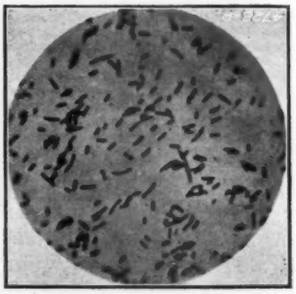


FIG. 23. SP. CHOLERA ASIATICA. AGAR CULTURE, 48 HOURS' GROWTH.

MAGNIFICATION 80 DIAMETERS. MAGNIFICATION 900 DIAMETERS.

per 24 hours the loss of head was 2 in. only. At a speed of 100 gallons it was increased to 7½ in., while a loss of head of 15 in. was absorbed with a delivery of 162 gallons per sq. ft. per 24 hours.

Daily readings of the thermometer taken during the hottest period of the year show that multiple filtration has no appreciable effect on the temperature of the water, although the whole of the filters at Cawnpore are exposed to the sun throughout the day.

Chemicals are never employed in multiple filtration as coagulants to arrest the passage of bacteria. Bacterial action is relied on to effect nitrification by natural means, and it appears to be established that the bacteria themselves perish as a result of the disappearance of organic matter to support them. There is no physical reason why bacteria should not pass through a sand filter, for

Cawnpore Waterworks, 1914. *Temperature Records. Degrees Fahrenheit. Averages of Daily Readings at 8 a.m.*

——	Raw Water.	After Settling-Tanks.	After Pre-filters.	After Final Filters.
May 20-31	81.08	82.45	81.49	81.75
June 1-30	84.5	85.4	83.73	84.7
July 1-31	83.8	84.7	84.06	84.00
August 1-12	84.00	84.75	84.58	84.58
Average for 85 Days.				
May 20-August 12 ..	83.69	84.63	83.64	84.01

if the particles of silt shown in photograph Fig. 21, above, will pass through a bed of sand 2 ft. 6 in. in thickness, it is evident that bacteria which are infinitely smaller could also pass. There are now over 50 large installations in which the Puech system has been adopted—that is, where the formation of a film on the surface of the filtering medium is prevented. Yet it is shown by analysis that the effluent from such filters reaches a higher degree of purification than can be attained with sand filters on which a film is allowed to form.

(To be continued.)

PITCHBLENDE RADIOGRAPHS. — The April number of the Journal of the Röntgen Society contains some interesting photographs which Mr. J. H. Gardiner, President of the Society, obtained by placing samples of pitchblende and other radioactive minerals from different sources directly on the sensitised film. The specimen was carefully flattened to give a good photographic record; sometimes a sheet of aluminium was interposed to stop the α particles and some of the β particles (the slower ones). The photographic records thus obtained showed characteristic differences between the pitch-blende from Joachimsthal and from the Trenwith mine, near St. Ives, Cornwall. Pitchblende is essentially uranium oxide (U_3O_8), but may contain from 2 to 80 per cent. of this oxide, together with iron and copper sulphides and other minerals. The Joachimsthal specimen was very rich in uranium, but there were white (inactive) patches in the black (active) portions, and the white patches were surrounded by peculiar fine white markings; a network of these white markings was visible all over the black portion. In the specimens from the Trenwith mine, which are not unimportant as a source of radioactive materials, the uranium oxide was much more finely disseminated, partly in very thin layers, and the mineral had evidently undergone violent distortion; the mechanical separation of the uranium oxide from the other minerals should yet not be difficult owing to its high specific gravity. Bröggerite from Moos, Norway, which is a complex vanadate of uranium and of thoria and other rare earths, again gave quite different radiographs. The radioactive value of these ores is determined by electroscopic tests; but the convenient photographic method may prove useful.

AMERICAN MACHINERY EXPORTS.—The value of the exports of machinery from the United States in the seven months ended January 31, this year, was 92,518,708 dols., as compared with 44,993,573 dols. in the corresponding period of 1914–15. The largest exports in the seven months ended January 31, this year, were metal-working machinery, which represented a value of 25,196,917 dols. The value of certain other exports was:—Gasoline engines, 4,423,507 dols.; steam-engines, 11,151,462 dols.; parts of engines, 3,714,109 dols.; milling machinery, 1,584,442 dols.; paper-mill machinery, 3,766,695 dols.; sewing-machines, 3,092,705 dols.; sugar machinery, 4,902,099 dols.; and typewriting machines, 4,654,166 dols The value of the machinery exported from the United States last year was 134,128,862 dols., and that of machine-tools, 41,037,779 dols. The American International Corporation has bought up the Allied Machinery Company of America, and proposes to extend the business of that undertaking, which aims at assisting American manufacturers of machine-tools to place their products in foreign countries. The company has show-rooms in Paris, Petrograd, Zurich, and Turin. Its branches in Austria and Hungary have, however, been closed since the outbreak of war, in consequence of transport difficulties.

CRANES AND GANTRIES AT THE WORKS OF THE ROTTERDAM DOCKYARD COMPANY.

CONSTRUCTED BY THE HAARLEMSCHE MACHINEFABRIEK, HAARLEM, AND ROTTERDAMSCHE MACHINEFABRIEK BRAAT, ROTTERDAM, HOLLAND.

(*For Description, see Page* 435.)

FIG. 4.

Fig. 5.

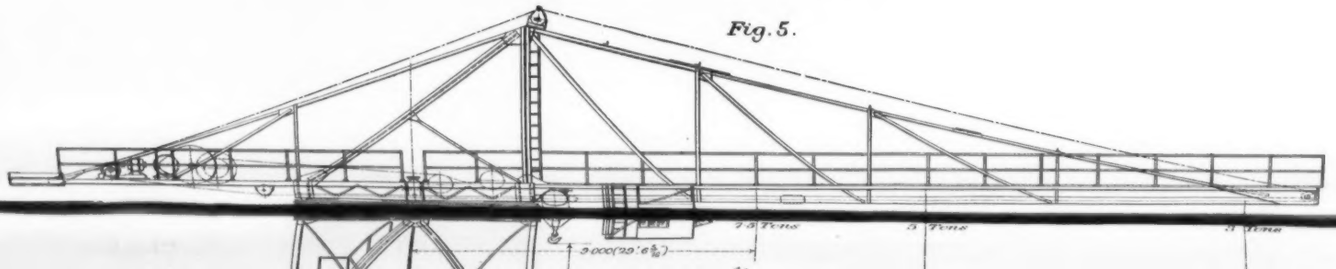
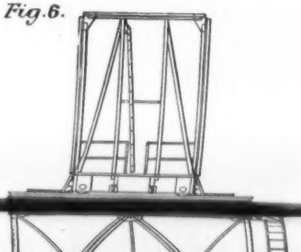


Fig. 6.



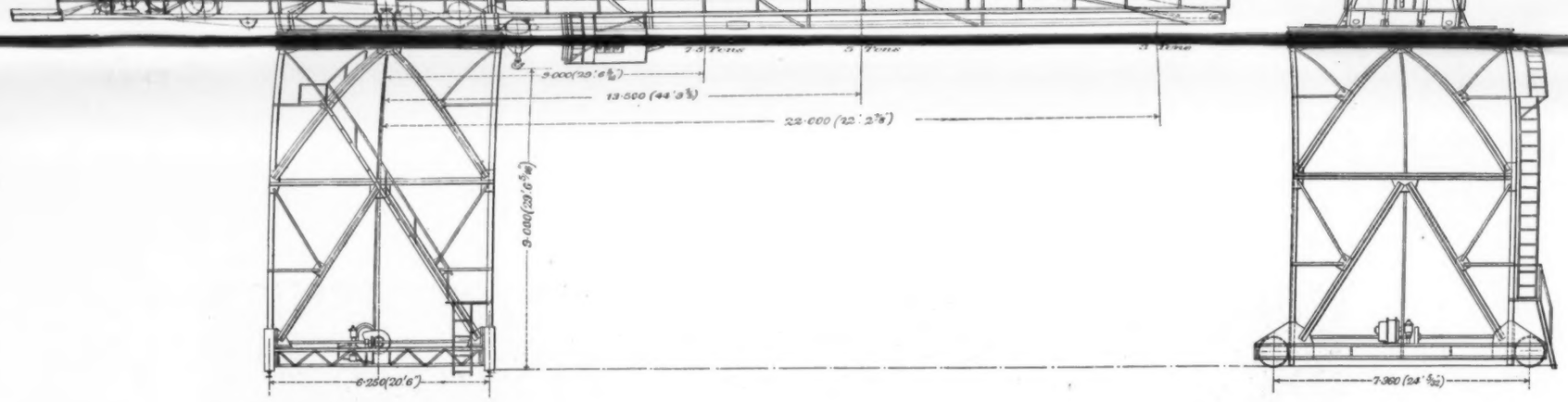


Fig. 1.

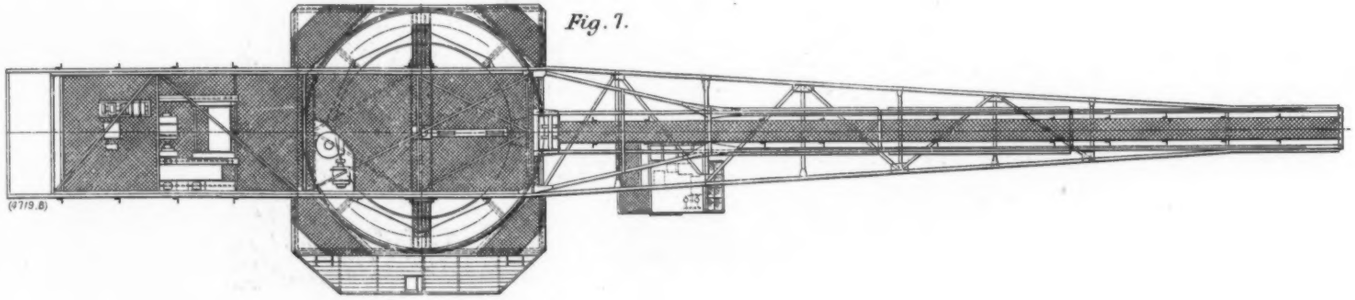


Fig. 8.

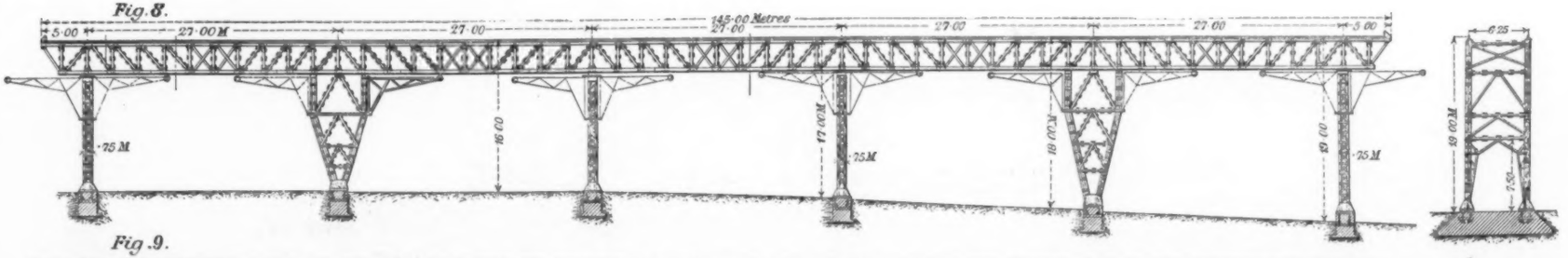


Fig. 9.

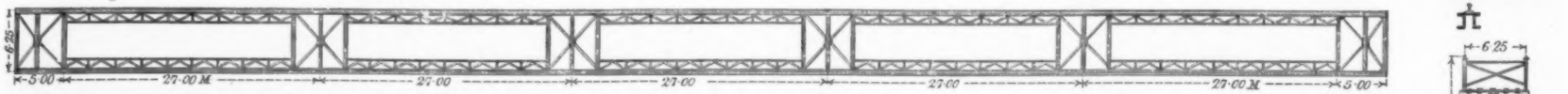
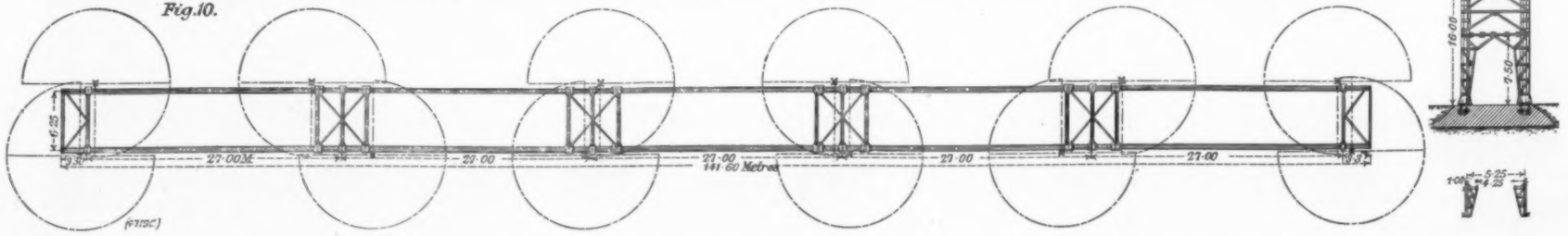


Fig. 10.



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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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TELEPHONE NUMBERS—3663 and 8598 GERRARD.

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With a Two-Page Plate of the CRANES AND GANTRIES AT THE WORKS OF THE ROTTERDAM DOCKYARD COMPANY

NOTICES OF MEETINGS.

THE ROYAL SOCIETY OF ARTS.—Monday, May 8, at 4.30 p.m. Cantor lecture.—"Vibrations, Waves, and Resonance," by Mr. J. Erskine-Murray, D.Sc., F.R.S.E., M.I.E.E. (Lecture II.) Wednesday, May 10, at 4.30 p.m. Ordinary meeting.—"Neutral Merchants and the Rights of War," by Sir Francis Taylor Piggott, M.A., LL.M., Chief Justice of Hong Kong, 1905-12. Mr. Dugald Clerk, D.Sc., F.R.S., Chairman of the Council of the Society, will preside.

THE SURVEYORS' INSTITUTION.—Monday, May 8, when a paper will be read by Mr. F. N. Keen, Barrister-at-Law, on "A Scheme for the Development of Agricultural Land." The chair will be taken at 5 p.m. instead of 8 p.m.

THE FARADAY SOCIETY.—Tuesday, May 9, at 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, W.C. (near Waterloo Bridge), when the following papers will be read:—"An Analysis of the Theory of Gels as Systems of Two Liquid Faces," by Mr. Emil Hatschek. "The Properties of Solid Solutions of Metals and of Intermetallic Compounds," by Mr. F. C. Thompson, M.Met., B.Sc. "The Annealing of Metals," by Mr. F. C. Thompson, M.Met., B.Sc. "The Changes in the Physical Properties of Aluminium with Mechanical Work:" ii. "Specific Heats of Hard and Soft Aluminium," by Mr. F. J. Brislee, D.Sc. "A Note on the Annealing of Aluminium," by Mr. Richard Seligman and Mr. Percy Williams. "Grain Size Measurements and Importance of such Information," by Mr. Zay Jeffries, B.S., Met.E. "A Contribution to the Theory of Solution," by Mr. E. J. Hartung, B.Sc. The Council invites contributions to the discussion from those unable to be present at the meeting.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, May 9, at 5 p.m., the annual meeting will be held at the House of the Royal Society of Arts, John-street, Adelphi, London. At the conclusion of formal business there will be a discussion on a Report to be presented by the Research Committee.

THE OPTICAL SOCIETY.—Wednesday, May 10, at 8 p.m., at the Rooms of the Chemical Society, Burlington House, Piccadilly, W. The following paper will be read and discussed:—"Apparatus used for the Teaching of Optics at the Cavendish Laboratory, Cambridge," by Dr. G. F. C. Searle, F.R.S.

THE PHYSICAL SOCIETY OF LONDON.—Friday, May 12, at 5 p.m., at the Imperial College of Science, Imperial Institute-road, South Kensington, S.W. Agenda:—1. "The Latent Heats of Fusion of Metals and the Quantum Theory," by Mr. H. S. Allen, M.A., D.Sc. 2. "Lenses for Light Distribution," by Mr. T. Smith, B.A. 3. "The Choice of Glass for Cemented Objectives," by Mr. T. Smith, B.A.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 12, at 5.30 p.m. A discourse will be delivered by Dr. A. C. Benson, C.V.O., LL.D. The subject is "Vulgarity." Afternoon lectures next week at 3 o'clock. Tuesday, May 9. Laurence Binyon, in charge of Sub-Department of Oriental Prints and Drawings, British Museum, on "Chinese Painting." (Lecture II.) Thursday, May 11. Sir Ray Lankester, K.C.B., LL.D., D.Sc., F.R.S., on "Flint and Flint Implements." (Lecture II.) Saturday, May 13. Professor W. H. Bragg, M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, on "X Rays and Crystals—First Results and their Applications." (Lecture II.)

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY MAY 5, 1916.

THE STAGES OF SCIENCE.

IF committees can save a nation, the security and future of this country are assured. We have quite lost count of the numerous bodies which have been appointed since the war began; probably nothing less than a card index would enable one to keep track of them. Some of them have done excellent work, especially in connection with munitions, but a large number have done nothing but issue preliminary programmes full of platitudes and generalities, and provide positions of notoriety for people of leisure. The weak point of committees is the difficulty of getting the right people to sit upon them, and the fatal ease with which the wrong people can be secured. It is not only wisdom that is wanted in a national crisis such as we are passing through; equally important matters are courage and driving force; and these can only be obtained by securing the services of men of affairs who are accustomed to make up their minds definitely and then to see that their ideas are carried out by others, using persuasion or authority to accomplish their ends. Unfortunately such men are generally fully occupied and can only take up new work by relinquishing something of importance. Certainly there are not enough of them to constitute one tithe of the new committees, and the result is that while many of these bodies consult and formulate, it is the exception for them to effect anything more. Among the numerous subjects which are the care of committees is the extension of scientific knowledge and practice among manufacturers, and many are the schemes which have been propounded to this end. Some progress has been made, for the Government has consented to find funds for research, and it is rumoured that a sum of a million sterling a year has been provisionally appropriated for distribution by a Committee of the Privy Council. It is easier, however, to allot funds in the gross than to deal with them wisely in detail, and there is every prospect of much of this money being wasted unless the Committee receives the accession of a considerable number of members who know in what direction research is immediately needed and how it ought to be conducted. There is no subject that requires more imperatively the guidance of a master—and masterful—hand than research. It opens up so many interesting and attractive avenues, it is so full of seductive invitations to by-ways, that the man of science is almost certain to be deflected from the main and immediate object unless he is conscious of a steady pressure directing him towards his goal, and urging him to be better satisfied with imperfect results which can be extended and rectified by commercial application than by far greater accuracy obtained by eliminating all difficult factors and working under conditions which never occur in practice. Pressure of this kind can only be exercised by those who understand thoroughly the needs of the times, and who have learned in the hard school of experience how wide is the gap which intervenes between the laboratory and the works. Fortunately there are many such among us who, at the call of patriotism, are ready to neglect their own affairs for the benefit of the nation, provided they are not asked to allow themselves to be controlled by a majority of academic colleagues, or to be carefully fettered by red tape before commencing operations.

During the present week there have been two notable utterances on the subject of engineering and scientific research by men whose record entitles them to speak with authority—that is, Sir William Beardmore and Dr. J. A. Fleming; and it is easy to see, reading between the lines, that each has spoken because he felt he must, because it was his duty to place the convictions born of years of experience before the nation at this parting of the ways. Both are representative of engineering and research, though of course in varying degrees, since Sir William is the head of a great and progressive manufacturing firm, while Dr. Fleming, although largely concerned with engineering matters, is more widely known as a teacher and writer and by his researches in radiotelegraphy. An opportunity of putting his views before the world occurred to Sir William Beardmore on his assuming the presidential chair of the Iron and Steel Institute yesterday. It is not often that a president-designate gets the opportunity of dealing with a great subject of immediate and pressing importance, and it is very seldom that he has the courage to do so, even if he have the chance. In this case the hour and the man came together, with the result that we get the thoughtful and highly practical address which we print on page 437 of this issue. The contrast between this address and many of the programmes which have been put forward on the same subject is striking, but it is only a reflection of the contrast which exists between the authors. Sir William directs a business—or rather several businesses—whose activities lie on the verge of the untried and unknown. His clients are always demanding something better than they have had before—tougher steel, more resistant armour plate, guns of greater power, ships of higher speed, engines of increased economy, new forms of motors and many other things—and always at the old price. Research is needed at every stage, and in addition to research imagination to extrapolate the results and courage to spend money with both hands on data which have to be weighed instinctively rather than judicially. With such an experience behind him Sir William speaks from a vantage point which commands respect, and his address will be read with interest by engineers and manufacturers all over the Empire.

There are two outstanding sentences in Sir William's address which are worthy of special consideration. These are: "It follows that research should be a charge on the selling price," and "There is still great need and great scope for research work in all factories." Not until the former of these is appreciated and acted upon can

we expect to make the progress we should. When we consider how freely money is spent upon selling goods, how large are the commissions paid to agents, what is the cost of advertising, and how miscellaneous expenses incurred in securing orders mount up, it is remarkable with what aversion all expenditure on research is generally regarded. Yet a step gained in economical manufacture, or an advance made beyond the capacity of competitors, is an asset which lasts for some time, while a sale is only an advantage for the moment, leaving the next order to be fought for as strenuously as before. But the second quotation is probably the more important. It reminds us that nothing pays like personal effort. All the present outcry for Government aid will expend itself on the air unless manufacturers realise that they too must bear their share of the burden. Such work as lies within their capacity they must do for themselves, and problems requiring greater knowledge or more ample appliances they must confide to experts, themselves undertaking to bear the cost. By these two means they will secure the kind of information which will be immediately valuable to them in their business. Paying the piper, they will be entitled to call the tune, while if they depend on Government aid they will probably find that they are treated to a measure to which they cannot dance. Further, they will secure the results of research for their own benefit and thus provide means for further inquiry. The existence of an adequate laboratory in a works, in itself, exerts a valuable influence in the place, as it establishes a standard of accuracy beside which rule-of-thumb methods stand somewhat abashed.

Research conducted by manufacturers, or at their expense, can never cover all the ground of our needs. It will naturally be directed to particular ends of more or less immediate interest, and will avoid the broader aspects of science which can only find their application in the future, and those branches of which the probable gain cannot cover the expense. Dr. Fleming, in his address last Monday evening before the Society of Engineers, recalled the fact that when anyone goes to well-known pocket-books or tables of engineering it is astonishing to find the wide gaps in our knowledge. The filling of these, and the determining of various physical constants of the materials used in engineering form one of the departments of research work which must depend upon endowment in some form. The development of new instruments and processes, such as delicate pyrometers and the microscopic examination of metals, must generally take place under conditions which are not commercial and which are only possible under some form of subvention, such as that under which professors are afforded a competence and the use of a well-equipped laboratory in return for a few hours' lecturing per week. The investigation of the deeper problems of the nature of matter and energy does not fall within the scope of the present movement, but it is pleasant to recall that Great Britain, in spite of its distrust of science and its niggardly reward of its representatives, has always stood in the foreground in the pursuit of pure science. What it will do if a fair share of the coming million finds its way to such institutions as the Cavendish Laboratory it will be interesting to see. Will the works of Joule, Kelvin, Clerk Maxwell and Thompson be rivalled by later investigators working under Government control and pay?

Important as money is to research, still more important are men. Nine-tenths of the work can be done by well-trained assistants, but at the present time these are not to be found in sufficient quantities to fill half the ambitious schemes which have been advocated. Dr. Fleming states that many of the students that pass through technical colleges emerge half trained because such a large part of the first and second years is occupied in teaching them what they should have learnt at school. The schoolmaster has been the object of attack by the scientist for years, but he has not paid much heed to it. At most public schools a scientific side has been introduced, but still the plums of the profession all fall to the classical men. It remains to be seen whether a great European war will effect sufficient revolution in popular ideas to coerce the schoolmaster to adopt a modern attitude. Only last Wednesday there was a notable gathering in the rooms of the Linnean Society, at which resolutions were passed calling upon the Government to promote the study of natural sciences by making them obligatory in the matriculation examination of the Universities, and also by requiring a knowledge of science from all candidates for the Civil Service and the Indian Service. These resolutions have a most influential backing, and it should be quite possible to get the latter part of the demand acted upon, since it could be given effect to by a departmental order and would not require legislation. Of course there would be a delay in enforcing it in the interests of the men who have already passed through a portion of their course of preparation.

We have no doubt that the schoolmasters will point to the engineering sides established in many public schools as evidence of their anxiety to meet the requirements of the country. We have never concealed our opinion that these sides are utterly useless for the purpose they are supposed to fulfil, and that the school years can be devoted to much better uses than amateur mechanics. The only intelligible defence we ever heard of them was that they furnished a useful field for the activity of boys who are incapable of book-learning. This, however, is only another evidence of the way in which schoolmasters make their arrangements for the benefit of a small minority of their scholars, to the detriment of the great majority. The study of Greek is maintained on the plea that it opens the door to the finest literature in the world. That is certainly true, but it is only one boy in five hundred that passes through the door. The rest are content to stay outside in happy ignorance of what they might find inside, although it has cost them some years of effort to gain the threshold. The dunces, of course, number more than one in five hundred, but still they are a small minority, and the money spent on the workshops would be better employed in increasing the equipment of the laboratories, which have a great attraction for many, and might be used to lay a foundation on which the technical colleges could build at once.

Both the addresses to which we have referred emphasise the fact that our present need is for increased means of applying science in industry. This country has always been fertile in men of pure science, and although it is but right that they should receive greater encouragement than they have done, yet it is the terrain between their field and ordinary manufacturing that stands in urgent need of intensive cultivation. Sir William Beardmore emphasises the need of manufacturers themselves undertaking that part of the work that lies close to the forge and the foundry, for no one else understands the conditions as well as they, or can bring the conclusions of the laboratory to the test of practice so readily. For problems a little more remote from daily work he advocates the employment of specialists in better-equipped laboratories. Dr. Fleming's address carried the subject a step further back, and dealt with researches of a more extended order, aimed at discovering the laws of thermodynamics, electricity, chemical action, metallurgy, and the like. Evidently these are beyond the resources of the individual manufacturer, but nevertheless they need to be directed by those who are familiar with commercial needs, and for this purpose the various great technical institutions stand as the natural agents. Some of them have already experience in research work, and all of them comprise many members who have spent years in the improvement of apparatus and processes before they became absorbed in management. No better means of securing an adequate return for the money which is to be allotted by Government could be devised than by securing the assistance of representatives of the institutions on the Central Committee and then of placing each individual research under the control of a committee of the corresponding institution.

Dr. Fleming concluded his address by a warning that the domain of science does not end with the manufacture of goods. Its functions embrace many other forms of social activity, and particularly that which we call "business." In no other department of life do we see so much wasted energy, so much opposed effort, so much wild scrambling and shuffling, as in business. Our commercial men seem to live like the barons of the Middle Ages, each with his retainers ready to make a foray into his neighbour's territory, or to repel a raid into his own. His own countrymen are as suspect as the foreigner; indeed, being nearer, they are the more feared. In ordinary life we have passed that stage, and walk the streets unarmed and unafraid. As to the foreigner, we sleep secure in the protection of our Navy. When shall we learn that wasted effort is as unscientific as wasted fuel, and that among the great forces of Nature to be still further directed to the uses of man are the British individualism and aggressiveness which, having served a purpose in the past, are now somewhat out of harmony with their environment?

WEST AUSTRALIAN RAILWAYS.

The report of the West Australian Government Railways for the year ended June 30 last shows that, owing to an unprecedented combination of adverse circumstances, the year's working resulted in a debit balance of 25,651*l.*, which compares very unfavourably with the credit balance of 128,160*l.* earned during the previous year. The effects of the war are partly accountable for this, but the principal cause was the disastrous drought which occurred early in the year, and resulted in an almost complete failure of the harvest. This was followed, in the latter part of the year, by a number of serious washaways, involving considerable expenditure for repairs.

The total main-line mileage was increased during the year dealt with by 365 miles 6 chains, making 3331 miles 75 chains, which, with 333 miles 75 chains of sidings, gives a total of 3665 miles 70 chains open for traffic. The most important new section opened, which has a length of nearly 200 miles, connects Wongan Hills with Mullewa in the South West division, and provides an alternative means of access to the Northern Railway. The Commissioner, Mr. John T. Short, points out that practically all the new lines constructed are for development purposes, so that they will have to be worked at a loss for some years. This is, of course, a serious drain on the profits from the paying lines, and, having regard to the fact that the railways are the State's main source of income, it is questionable whether the policy of construction can be safely continued until the population has been increased, or the State's resources augmented, sufficiently to warrant the increased liability. At present the capital expenditure on railways in Western Australia amounts to 53*l.* per head of population.

The total number of train-miles run during the year amounted to 5,404,814, which is 160,248 less than in the previous year. The earnings per train-mile fell from 97.34d. in 1913–14 to 91.4d. in 1914–15, and the working expenses were also reduced from 67.79d. to 66.51d. respectively for the two years. The net earnings therefore fell from 29.55d. to 24.89d. per train-mile, and, as the interest charges were increased from 24.02d to 26.02d., the profit of 5.53d. per train-mile of 1913–14 was transformed into a loss of 1.13d. in 1914–15. The diminution in earnings is largely due to the fact that, owing to the failure of the harvest, trucks had frequently to be hauled empty on the return journey, while services rendered free of charge to the Commonwealth Defence Department also added to the unproductive mileage.

The quantity of wheat transported during the year amounted to only 56,928 tons, as compared with 299,143 tons handled during the previous year; and the amount of local timber carried was also greatly reduced. The war has seriously affected the export of local timbers, and has resulted in the closing of a number of timber mills. On the other hand, a large quantity of sleepers and other materials for the construction of the Trans-Australian Railway have been transported, and this circumstance has helped to compensate for the loss of other traffic. The total quantity of paying goods handled amounted to 2,454,021 tons, and the revenue from this source was 1,257,902*l.*, whereas in the previous year the carriage of 3,101,918 tons of goods brought in 1,395,911*l.* A falling-off in

passenger traffic was also experienced, and this is attributed to the depression caused by the bad harvest and to the fact that so many men have left the State with the Expeditionary Forces.

As a result of the diminished revenue, it has been found necessary to increase passenger and goods rates in some cases; but as the amended rates only came into operation on April 26, 1915, their effect on the year's results would scarcely be felt. The rates for certain classes of goods have been increased on a sliding-scale, according to distance; season-ticket rates, prices of holiday excursion tickets, and parcel rates have been increased; and certain concessions to commercial travellers and traders have been abolished. As a further economy works in progress were suspended where possible, and several works which had been authorised were not commenced. Extensive resleepering, however, was found necessary, and sole-plates have been introduced on the sharper curves to prolong the life of the sleepers. New bridges and culverts had to be put in at about twenty places on the Great Southern Railway to cope with flood waters. The average number of persons employed in the railway service during the year was 7918, which is about 400 less than in the previous year, and is equivalent to 2.56 persons per mile worked. The average rate of pay to the salaried staff was 190*l.* 9s. 3d. per annum, while the average annual earnings of the wages staff, calculated for a year of 312 working days and exclusive of overtime, amounted to 158*l.* 2s. 4d.; both figures show a slight increase on those for the previous year. Industrial agreements with several of the men's organisations were due to expire during the year, but owing to the exceptional conditions prevailing, a mutual arrangement was come to for the extension of the existing agreements. Soon after the outbreak of war the Government decided that all State employees should work reduced hours, with a corresponding reduction in salaries or wages. The principle was duly applied to the railway staff, but, although the majority of the staff loyally accepted the altered conditions, it was found almost impossible to work the system satisfactorily. Shortly after the introduction of the scheme, it was found necessary to reinstate the locomotive men on full time, and a similar course had to be adopted in the traffic and way and works departments soon afterwards. Boilermakers, fitters, turners, and coppersmiths had also to be put on full time, so that, at the end of the year, only the officers and a small proportion of the wages staff were working short time. The Government then decided to resume full-time working in all departments as soon as circumstances permitted.

On the whole, the prospects for the current year are distinctly brighter, as the harvest promises to be a record one. There may, however, be some difficulty in providing the staff necessary to handle the increased traffic, since the loss of the more experienced men by enlistment has been serious. In all, 593 members of the staff had joined the Colours at the time the report was drawn up, and this fact naturally increases the difficulty of selecting and training men for the higher duties. However, careful management, combined with improving conditions and the economies mentioned above, will undoubtedly do much to restore the normal prosperity of the system; the report of the current year's working should therefore be of particular interest.

NOTES.

X-RAY DANGERS.

THE discussion on "The Injurious Effects Produced by X-Rays," which Dr. Sidney Russ introduced at a recent meeting of the Röntgen Society, made it clear that Röntgen-ray dangers persist, though science has certainly discovered how to protect the patient and, to a lesser extent, the operator, who works his tubes or bulbs for hours every day. It would be astonishing indeed if the dangers had vanished, for the tubes are now fifty times more powerful than they were in the early days which claimed their victims, and the war has multiplied the daily use of Röntgen rays at a terrible rate. Of the many scientists, medical men and instrument makers, who took part in the instructive discussion (see the April issue of the Journal of the Röntgen Society), only one medical man thought that the dangers, which he did not question, were sometimes exaggerated. All the others agreed that more had to be done to reduce the hidden risks to which patients and operators are exposed, though several speakers who had "dabbled" in X-rays almost since their discovery were able to assert that they had never felt any injurious effects. It is in general considered that certain minimum doses have no cumulative effects; yet there are observations on slow changes in the blood cells, about which little more can be said at present than that they claim serious attention. The point is, of course, that, except in cases of carelessness or of accidental conditions, the harm does not show until long after it happened, and that there is hardly any recognised remedy. According to some authorities, soft rays are more to be feared than hard rays, which simply pass through the system; this, we think, is a dangerous presumption. Several speakers complained about being completely tired out after a few hours ray work, not merely by the nervous strain, they thought, but by some change in the air of the room, possibly ionisation, which could not be cured by ventilation; others considered that the assumed ionisation was merely the production of ozone and nitrous oxides, always noticed where sparking was going on, and that efficient ventilation by two fans—not only by one fan—would keep the air wholesome. It is noteworthy in this connection that the Röntgen apparatus used to be put in small dark rooms, not to interfere with other work, nor to be interfered with, and that this unfortunate practice still prevails. The operator wants sufficient space to keep away from the bulb; he should certainly not stand in front of the opening, which should always be small. Rubber aprons and gloves are useful, provided they be not cracked, but may prove a snare: the operator may also retire behind a screen moving on rollers. On some elaborate couches the patient is endangered, because he is in certain positions too close to the source of the rays, especially if he should, before treatment, have been dosed with bismuth to facilitate the optical examination. The chief danger lies in the apparatus itself. Several experts declared that not 5 per cent. of the apparatus in use were really safe; there had been great difficulty, of course, in satisfying the demand for apparatus when the war broke out, but even now much of the glass of the tubes was not lead-glass at all, and unsuitable apparatus were being supplied. The bulb should be completely encased, except for the window, in a box lined with lead or with lead putty, *e.g.* Allusions to X-ray dangers in war hospitals were given with all reserve, of course; but it is clear that the dangers threatening from faulty apparatus will become accentuated there. One special point brought out during the discussion should be mentioned; it is that operators, doing photographic work (developing) at the same time, should be particularly careful, since washing the hands with alkali, *e.g.*, predisposes the skin to attack by the rays. The conditions which seem to make some people's constitutions more prone to dermatitis, &c., are not yet understood. A demand was expressed for some supervision, inspection, or registration of apparatus, by the Government, or preferably by the General Medical Council. It was pointed out that the sale of poisons was subject to registration. That parallel hardly holds; for it is the medical practitioner chiefly who needs protection from faulty tubes, whilst he can buy as much poison as he likes.

THE OSTWALD NITRIC ACID PROCESS.

The Ostwald process for the manufacture of nitric acid and ammonium nitrate from ammonia, which has recently received much public attention, represents a technical utilisation of laboratory reactions, which had so often been studied that the originator of the actual process, Professor Wilhelm Ostwald, of Leipzig, the well-known physical chemist and electrochemist, was refused a German patent, when he came out with his process about fifteen years ago. As early as 1839, F. Kühlmann oxidised a mixture of ammonia and air or oxygen with the aid of a catalyst, the products being nitrous and nitric acids, which combine with the excess of ammonia to nitrite and nitrate of ammonium. Like all catalytic reactions in particular, however, this oxidation required a great deal of working out by the physical chemist and engineer before it became a practical success. Ostwald's first British patent (No. 698, of 1902) spoke of the platinum metals in the spongy condition, and of the higher oxides of manganese, iron, cobalt, nickel, lead, copper, &c., as suitable catalysts; later additions to the patents pointed out that a catalyst consisting entirely of spongy platinum was too active, so that free nitrogen was liberated instead of nitric acid, just as certain bacteria in the soil carry the decomposition of the complex nitrogen compounds in the soil to the undesired liberation of free nitrogen. To obviate this drawback, Ostwald covered the platinum partly only with spongy platinum; the reaction was to take place at temperatures somewhat above 300 deg. Cent.; continued heating was unnecessary. He did not propose to isolate the ammonia first, but he took it from the ammoniacal liquor of gas works, and passed it through the outer of two concentric tubes into the inner tube, which was packed with the catalyst, the two currents being in opposite directions, the air-ammonia mixture was sucked from the liquor into the tubes. The yield of acid depends upon the temperature, the composition of the ammonia-air mixture, and the rate of flow. A complete oxidation to nitric oxide is not possible, and in practice it is said to be best to conduct the operations in such a way that ammonium nitrate is formed. This nitrate contains 35 per cent. of available nitrogen, and is much more valuable as a fertiliser than ammonium sulphate or sodium nitrate from Chili or elsewhere. The ammonium nitrate can be converted into nitric acid in various ways; on the other hand, nitric acid can be prepared from calcium nitrate or nitrite (obtained in Norway, *e.g.*, by the electric oxidation of nitrogen), and calcium cyanamide, or nitrolim, which in their turn are also sources of ammonia supply. Thus the two industries have become associated, and these processes have a good many rivals. It has been proposed, for instance, to dissolve calcium nitrate in ammonia water and to precipitate the calcium by the carbonic acid from lime-kilns; ammonium nitrate would result. Frank and Caro use thoria as a catalyst for nitric acid manufacture, the advantages of thoria being that it swells and offers a very large surface. In how far these methods are really utilised can hardly be said. Secrecy is the rule in chemical works, and it was particularly observed in the case of the Ostwald process because the process was not covered by any German patents, though British, French and American patents were granted. The nitric acid produced by these various processes is generally weak; to concentrate it, E. Brauer, who was associated with Ostwald in these investigations, adds phosphoric or arsenic acid to the weak acid and distils a strong nitric acid off. Ostwald himself, who was born and educated in Russia, by the way, and was professor there until called to Leipzig—professors frequently were called from one part of the Continent to another—had a serious breakdown in health some years ago, and took no further part in the development of his process. Nitric-acid works were started at Gerte, near Bochum (in the Ruhr coal basin) in 1909. These works (and those built or projected in Belgium) passed in 1911 under the control of the Nitrite Products Company, of London, which in 1913 disposed of its interests (or part of them) to the Nitrogen Products and Carbide Company; the latter company erected works in Essex and elsewhere. The Haber process, which has been mentioned in the daily Press in connection with the Ostwald process, really concerns the synthetic preparation of ammonia from hydrogen and nitrogen by the aid of catalysts at high pressures and temperatures. This process has been taken up by the Badische Anilin und Soda-Fabrik; its theoretical and experimental basis was discussed, in the *Zeitschrift für Electrochemie*, at considerable length, by F. Haber and his collaborators last winter. Everything connected with the production of nitric acid is of great interest at the present time.

THE IRON AND STEEL INSTITUTE.

THE forty-seventh annual general meeting of the Iron and Steel Institute was held yesterday and is being continued to-day at the hall of the Institution of Civil Engineers, Westminster. The Acting-President, Mr. Arthur Cooper, LL.D., occupied the chair at the beginning of the proceedings. He referred to the death of the late President, Dr. Adolphe Greiner, who was held by all in the greatest esteem. At the meeting of the Council which had just been held a vote of condolence was passed. This was put to the general meeting, and was carried unanimously, all members rising in their places.

THE REPORT OF THE COUNCIL.

The report of the Council also opened by recording with feelings of profound regret the death of the President, Dr. A. Greiner, which took place after a long and severe illness at his residence near Liége, on November 20, 1915. Condolences on behalf of the Council and members had been transmitted to Madame Greiner, to the other members of Dr. Greiner's family, and to the Cockerill Company, and the manifestation of sympathy had been universal.

The report stated that thirty-eight new members were elected during the year, a figure considerably below the average. The total membership of the Institute on December 31, 1915, was: Patron, 1; honorary members, 4; life members, 65; ordinary members, 1923; total, 1993.

The question of the position of those members subjects of the countries with which the United Kingdom is at war at the present time, having been raised at the last annual meeting, it was decided to amend the bye-laws of the Institute so as to provide for the future that, in the event of war existing between this and other countries, citizens or subjects of which were honorary members or members of the Institute, such honorary members or members should *ipso facto* cease their membership. At the autumn meeting new draft bye-laws were prepared with the object of giving effect to the resolution passed at the annual meeting, and these were now to be submitted for final consideration.

The Council took the opportunity of the meeting to tender their congratulations to several members who had honours conferred upon them. The Duke of Devonshire had been created Knight of the Garter and had been appointed Civil Lord of the Admiralty. Mr. Arthur Balfour had been appointed Belgian Consul in Sheffield, and Colonel Herbert Hughes, C.B., Vice-Consul for Sweden in Sheffield. Sir R. A. Hadfield, Mr. Andrew Carnegie, and Mr. Alexander Siemens had been elected Managers of the Royal Institution of Great Britain. The degree of Doctor of Science of Birmingham University had been conferred upon Mr. O. F. Hudson. Sir H. F. Donaldson, K.C.B., had received the appointment of Technical Adviser, and Mr. F. W. Harbord that of Hon. Metallurgist to the Ministry of Munitions. Mr. Vincent L. Raven had succeeded the former as Superintendent (temporary) of the Royal Arsenal, Woolwich, and about eighty-seven other members had received appointments under the Ministry of Munitions. Mr. G. T. Beilby and Professor Bertram Hopkinson had been appointed Members of the Advisory Council for the Organisation and Development of Scientific and Industrial Research. Mr. Léon Greiner had been appointed Director-General of the Société John Cockerill, in succession to his father, the late Dr. Adolphe Greiner.

During the year 1915 the Institute had the misfortune to record the death of its President and a number of other well-known members. Among the names are those of Mr. William Evans, Merthyr Tydfil, vice-president; Mr. Arthur Keen, Birmingham, vice-president; Mr. Erik Johan Ljungberg, Falun, Sweden, honorary vice-president; and the Right Hon. Lord Glantawe, Swansea.

The statement of accounts for the year 1915 showed the total receipts to have been 5759*l.* 15d. 5s., whilst the expenditure was 4775*l.* 5s. 3d., the excess of income over expenditure being thus 984*l.* 10s. 2d.

ORGANISATION OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

During the year 1915 the Privy Council appointed an Advisory Council to promote a scheme for the Organisation and Development of Scientific and Industrial Research, and the Council of the Iron and Steel Institute, having been invited to discuss the matter, appointed a committee, consisting of Sir William Beardmore, Bart., Sir Hugh Bell, Bart., Dr. H. C. H. Carpenter, Dr. Arthur Cooper, Sir Robert A. Hadfield, F.R.S., Mr. Frederick Mills, and Dr. J. E. Stead, F.R.S. This Committee drew up proposals as to subjects for the investigation of which a Government grant might be usefully applied, and their proposals had been submitted for the consideration of the Advisory Council.

APPOINTMENT OF REPRESENTATIVES.

The report concluded by giving the names of the members who represented the Institute on various public bodies, and added that Professor D. Tschernoff, of Petrograd, who was elected a member in 1890, had been appointed an Honorary Vice-President of the Institute.

NEW BYE-LAWS.

The Acting-President then moved the adoption of the proposed new bye-laws, as amended at the autumn meeting, for incorporation in the bye-laws of the Institute. These read as follows:—

1. In the event of a state of war existing between the United Kingdom and any other country, or State, all members, honorary members, and honorary vice-presidents who shall be subjects of such enemy country, or State, shall forthwith cease to be members, honorary members, or honorary vice-presidents of the Institute, but they shall be eligible for re-election after the war in the usual manner.

2. The Council shall have absolute power to remove from the list of Members of the Institute the name of any member, whether ordinary or honorary, for wilful contravention of the bye-laws or for any other reason which seems to them sufficient, and such ordinary or honorary member shall thereupon cease to be a member of the Institute.

The motion was seconded by Mr. G. M. Ritchie and supported by Mr. W. H. Hatton. It was carried *nem. con.*

Mr. Ritchie then, referring to the change in the Presidency of the Institute, said the meeting could not allow the occasion to pass without calling for a hearty vote of thanks to their retiring President for the tact and courtesy he had shown from first to last. The vote was passed with acclamation.

THE NEW PRESIDENT.

Dr. Cooper, the Acting-President, welcomed the thanks of the members, and after a brief reference to Sir William Beardmore's career, then proceeded to induct him into the chair as his successor.

THE BESSEMER GOLD MEDALLIST.

The first duty performed by the new President was to present to Mr. F. W. Harbord, F.I.C., the Bessemer Gold Medal for 1916, as an acknowledgment of the research work he has done for very many years.

In making the presentation, Sir William Beardmore stated that Mr. Harbord was an Associate of the Royal School of Mines; a Fellow of the Institute of Chemistry and of the Chemical Society; Vice-President of the Institution of Mining and Metallurgy; Past Vice-President of the Faraday Society; Past-Member of Council of the Institute of Chemistry and of the Society of Public Analysts. After he left the School of Mines, Mr. Harbord was for a short time with Dr. J. E. Stead, Middlesbrough. He was then appointed Metallurgical Chemist at the works of Sir Alfred Hickman and the Staffordshire Steel and Ingot Iron Co. He then became manager of the steel works of Messrs. Hatton, Sons and Co., Bilston. In 1892 Mr. Harbord was appointed Metallurgical Chemist to the Government of India, at the Royal Indian Engineering College, Cooper's Hill, where he was responsible for the greater part of the analytical work connected with the Indian Government Railways. In 1904 he was appointed metallurgist to a Canadian Government Commission, to investigate and report on electric smelting in Europe. In 1909 he was appointed by the Transvaal Government to visit that country and report on the possibilities of iron and steel manufacture in South Africa. For eight years previous to the war Mr. Harbord was a Civil Member of the Old Ordnance Board; he is at present a Civil Member of the New Ordnance Committee, and is also acting as Honorary Metallurgical Adviser to the Ministry of Munitions. He is the author of a well-known treatise on "The Metallurgy of Steel," and he revised and enlarged the sixth edition of Roberts-Austen's "Introduction to the Study of Metallurgy." On the closing of the Royal Indian Engineering College in 1905, Mr. Harbord started in private practice as a consulting metallurgist and chemist. In 1908 he went into partnership with the late Mr. Edward Riley, and is now the senior partner in the firm. Mr. Harbord has also had a large experience in general metallurgy, especially in the electric smelting of zinc.

Mr. Harbord said he found it difficult to find words for expressing the gratitude he felt for the great honour which had been conferred upon him. The first meeting of the Institute he attended was the one at which the Bessemer Medal had been conferred upon Mr. Sidney Gilchrist Thomas and Mr. G. J. Snelus. He was then only a student. When he considered the work which these men and others, commencing with Sir Lowthian Bell, had done in metallurgy, he realised how little he himself had done in the same field. It was, however, given to but few to revolutionise industry, other men had to till their small patch, and to do it with care and diligence. His (the speaker's) book on the "Metallurgy of Steel" had been referred to, and he desired to take that opportunity for identifying his colleague and friend, Mr. J. W. Hall, for the kind help he had received from him in its production, notably in regard to the mechanical section of the work. He thanked the President for the kind words he had spoken, and hoped that the future would justify them.

PRESIDENTIAL ADDRESS.

The President next proceeded to deliver his presidential address. We reproduce this in full on page 437 of the present issue, and we have dealt with it in an article on page 427.

A vote of thanks to the President for his address was moved by Sir Robert Hadfield, who said he felt sure he expressed the feeling of the members when stating that the address was a most magnificent one, full of advice. The Institute was very fortunate indeed in having Sir William for its President in the present time of stress; his works were giving all possible help to the nation, from the construction of warships down to the manufacture of small shells. He had introduced female labour in his establishments and had made of this a success; he (Sir Robert) congratulated him on his efforts in that direction. Sir William would give them good advice and they would find that he did what he preached. Sir Robert wished to emphasise a paragraph in the address, that where the saving was pointed out arising from the use of special sheets in the building of electric transformers. The first transformer using these sheets was built in Sheffield in 1903; it was only a small one, and the figures given by the President showed how large the developments had been. This was one encouragement, among others, towards the making of experiments. And for realising such progress in all spheres it was not necessary to go abroad, as was evidenced by the instance of that small experiment made in Sheffield as far back as thirteen years ago. He put the vote of thanks to the meeting and this was most heartily responded to.

Mr. B. Talbot asked whether a special meeting of the Institute could be convened so as to call the attention of the State to the fact that the Institute was in a position to give it advice. If it was in order, he suggested that such a special meeting should be called to discuss the point, the considered views of the Institute being then sent to the Government.

In reply, Sir William Beardmore said the Council would consider the point raised by Mr. Talbot, and would give a reply at the next (to-day's) meeting.

The two following papers were then taken and discussed:—"The Influence of Carbon and Manganese upon the Corrosion in Iron and Steel," by Sir Robert Hadfield, F.R.S., and J. Newton Friend, D.Sc. "The Theory of the Corrosion of Steel," by Leslie Aitchison, M.Met., B.Sc.

We shall deal with these and with the continuation of the proceedings in our next issue.

INDUSTRIAL NOTES.

THE Government issued on the 1st inst. a list of certified occupations, from which we take the following notes. The figures given represent the minimum age at which the single men are not exempted from military service :—

Agricultural implement and machine making, erecting and repairing: foreman, 30; all other classes of workmen except woodworkers and painters, 25. Blacksmith (including farrier), 25; cast and wrought-iron domestic and sanitary-ware manufacture: foreman or charge-hand, 30; cupola man, moulder, grinder, drop hammersmith, lathe-hand, annealer, tinner, enameller, pickler, burner or fuser, galvaniser, 41. Dairy appliance manufacture: foreman, 30; sheet-metal worker, blacksmith, tinner, filler and erector, 25. Electric accumulator manufacture: Departmental manager, foreman, 30; caster, mixer, paster, lead-burner, forming man, battery erector, 25. Heavy edge-tool manufacture: All classes of workmen, except wood turners, 30. Weighing machines: Adjuster and repairer, 30. In the textile machinery accessories trades, the minimum age limit is 30, except in the case of bobbin rougher, tuner, bobbin maker-ready, machine man, bobbin finisher, and cord, comb, hackle and gill-pin maker, for whom the minimum limit is 41.

Men who on November 2, 1915, were unmarried, or were workers without any child dependent on them, are to be treated as single men.

With the exception of those employed in ship or barge building and repairing, marine engineering, and by railway companies, men in the occupations included in the list are covered only if they can show that they were engaged in the same occupation on or before the date when the National Register was made, namely, August 15, 1915. The cases of men who have entered coal-mines since this latter date are being considered by the special Mining Courts.

The Minister of Munitions announced last week that he had made a further Order under the Munitions of War Act, 1915, under which 156 additional establishments have been declared controlled establishments. A total of 3493 establishments has now been declared as controlled from the date of the first Order, July 12, 1915, up to May 1, 1916.

The Scottish Trade Union Congress opened at the Scottish Co-operative Society's Hall, Kingston, Glasgow, on Thursday, April 27. There were present about 150 delegates, representing over 300,000 trade unionists. Mr. David Gilmour, general secretary of the Lanarkshire County Miners' Union, occupied the chair. In the course of his address, the chairman referred to the war and stated that, in common with the majority of his colleagues on the Parliamentary Committee, he had from the commencement held the view that this country had been in no way to blame for the calamity which had overtaken the world. He added the Committee was now dealing with the problems which would arise at the termination of the war; these problems included the re-employment of all soldier comrades in civil industry at the termination of the war, the State to undertake proper responsibility in regard to men and women displaced at the end of the war, to make room for the returning soldiers and sailors; the restoration to the trade unions of all rights and practices in the workshops existing at the beginning of the war; the seeing that taxation to meet the costs of the war be placed on the proper shoulders; and to press the Government to undertake the proper housing of the people. A resolution was passed advocating the establishment by law of a general minimum wage.

On the following day, April 28, a resolution was passed for discouraging the formation of new unions in industries where bona-fide unions already existed. A motion was also carried dealing with the evils of the liquor traffic, and demanding that Government should at once take steps to abolish the traffic. Resolutions were also passed for improving the housing conditions in Scotland and for securing the restriction of the employment of female or other unskilled labour in the various industries and trades.

The concluding meeting was held on Saturday last, April 29, and dealt mainly with conscription.

The Minister for Lands of New South Wales recently stated that he hoped to have 4000 homestead farms made available for soldiers within the next two years without interfering with ordinary settlement. The Government has decided that advances shall be made up to 500*l.* upon improvements, and for the purchase of stock and implements. It is intended to introduce a Bill into the State Parliament so as to ensure the settlement of soldiers on the land with no dislocation of ordinary settlement, and for the purpose of the scheme it is to be presumed that the war will be over by the end of the present year, and it is hoped to have ready large areas of wheat, dairying, and orchard lands, and also a number of irrigation areas. It is hoped to open up extensive new country by means of additional stock routes and new railways, and the efforts of the Government will undoubtedly be extensively supplemented by private enterprises such as that organised by Dr. Arthur, M.L.A., at French's Forest, where 27 farms for returned soldiers have been allotted. In connection with this latter scheme, cottages are being specially constructed and the occupiers will only repay 100*l.* (at the rate of 5*s.* per week) out of the cost price of 150*l.* At the last meeting of the Board of the British Immigration League, the following motion was unanimously carried :—

"That, inasmuch as the Empire's forces have been and are fighting for all the Empire possesses, the men and their dependants, including war widows, are, in our opinion, entitled to have the best of our lands reserved, upon which they may be provided with homes and occupation. Further, that attempts to induce widows and maimed soldiers or others to settle on lands of an inferior or doubtful quality should be strongly resented."

The Federation of Master Cotton-Spinners' Associations, says the *Textile Mercury*, have now before them the application of the Cardroom Amalgamation for a 10 per cent. advance in wages, in addition to a similar application from the Operative Spinners' Amalgamation. It is not yet possible to say what procedure will be taken in dealing with these claims, but in all probability they will be taken up by the Committee on Production, as was done last year, when an application for a 10 per cent. increase in rates of pay was before the industry. In order to escape the binding terms of the Munitions Act, the operatives had previously consented to seek pacific means of dealing with wages questions, or with any other form of dispute, and if strike notices are handed in, this course will, no doubt, be adopted, in order to strengthen the applications in the view of the Government Committee appointed since the war to settle differences between employers and workpeople.

The report for April, recently issued by the National Union of Boot and Shoe Operatives, states that with very few exceptions employment continued very good in all the principal districts, and on the whole, there was little change compared with a year ago. Some temporary dislocation and reorganisation of departments was reported in some cases, owing to the gradual depletion of male labour, but female labour was being gradually introduced to an increasing extent where practicable. Returns of firms employing 63,398 workpeople in the week ended March 25 showed an increase of 0.2 per cent. in the number employed and also in the amount of wages paid compared with a month ago. Compared with a year ago, there was a decrease of 3.3 per cent. in the number employed, and an increase of 3.5 per cent. in the amount of wages paid. The exports of boots and shoes of leather in March, 1916, amounted to 115,331 dozen pairs, compared with 103,231 dozen pairs in February and 100,983 dozen pairs a year ago. The number of financial members now serving with the colours is 8648; by adding to this figure the probationary members, the total number now serving amounts to approximately 11,000.

X-RAYS AND CRYSTAL STRUCTURE.

ON the occasion of the Sixth Annual May Lecture of the Institute of Metals, delivered yesterday, May 4, at a meeting of the Institute in London, Professor W. H. Bragg, D.Sc., F.R.S. (Nobel Prizeman), gave an interesting account of the new method of applying the properties of X-rays to the study of crystal structure, including the structure of certain metals. The method, it was shown by the professor, results in the determination of the exact relative positions of the atoms of which the crystal is composed. It is not successful in every case as yet, because of the lack of practice and experience of the experimenters in the new field, and because some of the interpretations are not fully understood. There is no lack of indications, but we are not yet fully aware of the meaning of all of them.

It is natural to attack first such crystals as have an obviously simple structure, and consist of few elements associated in simple proportions. It is also of great advantage if the crystals belong to a group of isomorphous members, such as the rock-salt series. This series, in fact, has everything to recommend it to the experimenter: its form is simple, that of the cube; its symmetry is high; it contains two elements only, in equal proportions, *e.g.*, sodium or potassium associated with chlorine or iodine; and there are several members of the series, so that we can watch the effect of changing one element at a time. The constitution of this series was therefore one of the first to be examined and made plain. The constitution of the diamond, which has also been determined, presented a rather more difficult task, because the arrangement of the atoms is not so simple as that of the rock-salt series, although its form is cubic, its symmetry is high, and it contains atoms of one kind only.

Of the metals which will naturally be of especial interest to the Institute of Metals, silver and copper—and, by inference, gold—have been shown to possess a very simple structure, in which the atoms are arranged as in the piling of shot. Bismuth and antimony have a distorted arrangement; but these two, as well as zinc, have not been completely determined. A beginning had been made with iron. The war has, however, stopped all work of the kind on this metal.

This new field of research, according to Professor Bragg, depends on a principle already known. When a regular train of waves falls upon a surface separating two media, part is reflected and part goes on. If the part that goes on meets another separating surface, a second portion is reflected, and some of this emerges from the second medium in the same direction as the beam reflected from the first surface. It will happen in general that the two reflected beams are out of phase, and to that extent destroy one another. Whether they do so or not depends upon the relation between the wave length, the angle of the inclination of the beam to the reflecting surfaces, and the distance between the surfaces. In this way are explained the colours of the soap film, of the thin layer of oil on the surface of a liquid, of the colours of steel when being tempered, and so on.

If the reflecting surfaces are many in number, not two, the effect is made more intense, and at the same time more precise. It occurs in the beautiful colours of potash crystals as shown by Lord Rayleigh. These crystals are formed of alternating layers, twinned across their surfaces of separation, and for some obscure reason the thickness of all the layers is the same, though it varies from crystal to crystal. When white light containing all wave lengths is incident upon such a crystal, at a certain angle, then only that wave-length is reflected for which the proper relation between the wave-length, angle, and spacing holds good. If the angle is altered the wave-length which is reflected is no longer the same. Hence the beautiful play of colours which the crystal shows. It is an essential cause of the success of this wonderful effect that the wave-length and the spacing are not very different in amount.

We now pass on to the case of the X-rays. These consist of waves—so, indeed, these very experiments tell us—which are something like ten thousand times shorter than the wave length of light. To obtain the parallel effect we must look for reflecting surfaces which are ten thousand times closer together than the twinning surfaces of the chlorate of potash crystals, and these are separated from one another by only the forty-thousandth of an inch or thereabout. These also Nature has provided in the layers of atoms in the crystal.

It may seem curious that a layer of atoms should act as a reflecting surface; but after all it is not necessary that such a surface should be continuous. A row of iron railings, for example, can act as a reflector of sound-waves. A natural face of a crystal contains no doubt a layer of atoms arranged regularly, and behind the natural face are other layers all similar, and placed at regularly increasing distances behind it. Thus all the conditions for this peculiar reflection experiment are present, and we actually find that when a pencil of X-rays of a definite wave-length are allowed to fall upon the face of the crystal, and the crystal is gradually turned round so as to alter the angle of incidence, the reflection of the beam as a whole is non-existent, except when the angle is right. Then it flashes out strongly. When this angle is observed, the relation of the wave-length to the spacing is known.

The instrument used is called the X-ray spectrometer. It has no lenses, because X-rays cannot be refracted, and the rays are invisible, so that in place of the telescope appears a chamber containing gas which is ionised by the X-rays. The resulting electrical effect is observed in an electroscope. It is important that the measurement of the result is quantitative, so that in this respect the new spectrometer has an advantage over the old.

In this way, if we use always the same X-ray we can compare the spacings between the layers parallel to one after another of the natural faces parallel to the crystal; and in this way we arrive finally at the crystal structure. The instrument is not at all difficult to use, and the observed effects are large and precise, so that it is quite easy to get numerical results. The interpretation is not always quite so easy. One part of it comes readily, viz., the number of molecules to each unit of the pattern of the crystal, the unit being the smaller part, which, being reflected again and again without alteration of orientation or distance from its neighbours, forms the complete crystal. For instance, the unit of pattern of potassium sulphate contains four molecules, the unit of pattern of antimony contains two atoms. The far greater difficulty lies in the determination of the way in which the atoms are arranged in the unit. These data are sufficient, but the interpretation is hard. To understand how it is attempted, and in some cases achieved, is best explained by models.

THE ARMAMENT OF ZEPPELINS.—The armament of the more recent types of Zeppelins includes, according to the *Rivista Marittima*, six machine-guns, two quick-firing guns, a launching apparatus for aerial torpedoes very similar to a ship's torpedo-launching tube, and various apparatus for dropping bombs. The gondolas are protected by armour which is proof against rifle bullets and also against splinters of anti-aircraft projectiles when fired from a certain distance.

DIRECTORY OF PAPER-MAKERS, 1916.—This directory of paper-makers of the United Kingdom, the fortieth annual edition, is published by Messrs. Marchant Singer and Co., 47 St. Mary Axe, E.C., at the price of 1*s.* net and 1*s.* 5*d.* post free in the United Kingdom. It gives an alphabetical list of paper and millboard makers, the information comprising the address of each firm, the types of paper manufactured, location of works, &c. The makes, water-marks, and trade names are classified separately.

BOILER EXPLOSION ON BOARD SHIP.

A FORMAL investigation under the Boiler Explosions Act, 1882, has lately been conducted by the Board of Trade at the Guildhall, Southampton, with regard to the cause and circumstances of an explosion which occurred on board the steamer La Marguerite on September 28 last, when the vessel was proceeding down the channel on its way to Southampton. As a result of the explosion four of the stokers were killed by the escaping steam and two others injured. The Commissioners were Mr. A. A. Hudson, K.C. (presiding), and Mr. J. Melrose, C.B., J.P., R.N. The Board of Trade was represented by Mr. G. C. Vaux; Mr. S. H. Emanuel appeared for Mr. McEwen, the chief engineer of the vessel, and several members of the engine-room staff; while Mr. Holmes appeared for the owners of the vessel, the Liverpool and North Wales Steamship Company, and for Mr. Fraser, the superintendent-engineer of the company.

At the inquiry conducted by the coroner at Dover a day or two after the explosion, the second engineer of the steamer gave particulars of the occurrence. He went on duty about 6 o'clock and shortly after looked at the water-gauge and saw that the glass showed plenty of water. At 6.50 he saw a jet of steam coming through the fan opening which connected with the stokehold and heard cries for help, but could do nothing as the place was filled with steam. With difficulty, he, with the assistance of two of the oilers, managed to get to the forward boiler and shut the valve; they then got into the stokehold and found three of the men dead, and another man so injured that he died the next morning. Witness examined the combustion chamber of the boiler and found that the 12 roofing-stays had pulled away. He could not give any reason for the cause of this happening, but in his opinion the strength of the steam did it, and there might have been some defect in the stays. The blowing-off pressure showed 125 lb. on the square inch. In reply to the coroner, witness said he was not aware that there was any defect in the water supply, but the gauge was quite right; the stays were clean broken, the thread of the nuts being pulled off, which one would naturally find in a combustion chamber after having come down.

Mr. Thomas R. Little, consulting engineer and naval architect, Liverpool, gave evidence and said he acted as consulting engineer to the owners of the steamer La Marguerite. The boilers in the vessel were built and fitted under his supervision by Cammell, Laird and Company in 1910. There were four double-ended boilers with six furnaces in each and three combustion chambers. The explosion occurred in the starboard aft boiler; the port combustion chamber had collapsed, and the plate, coming down, had stripped or broken the 12 roofing stays, leaving an opening for the steam to escape into the stokehold. The boilers were designed for a working pressure of 130 lb. and were capable of standing five times that amount. The collapse was due to the overheating of the crown-plate through either shortness of water or some deposit, such as grease, getting on the surface of the plate and preventing intimate contact with the water. There was, witness said, no evidence of grease in the boiler, but it might have changed its composition in the overheating. There was no trace of grease in the other boilers, but it might be present and do damage without being visible, except by an analysis which, in this instance, would be made; a thin layer of grease would be sufficient to cause the plate to be overheated. A possible cause of shortness of water would be a defect in the pumps which, however, would only lead to a gradual shortage; the plate was not split, but had simply dropped; the scale in the boiler was only $\frac{1}{16}$ of an inch thick, and witness was certain that the collapse was not due to the presence of incrustation; the boilers were in splendid condition and free from defects.

At the formal inquiry held by the Board of Trade, Mr. Vaux laid before the Commissioners full particulars of the vessel and of the explosion. The steamship La Marguerite was, he said, of 1558 tons gross register, and before the war was used for carrying passengers and for excursion traffic. The boilers were constructed for 130 lb. working pressure and were built under the Board of Trade survey in accordance with plans approved by Mr. T. R. Little, consulting engineer to the owners, and since being installed in the vessel they had been periodically inspected by the Board of Trade surveyors. Under certain circumstances, which Mr. Vaux referred to, the vessel was chartered by the Admiralty and used for certain services. The engine room staff on board at the time of the explosion included the chief engineer, Mr. McEwen; the second engineer, Mr. Edward Durbrow (both holding first-class Board of Trade certificates); Mr. Ellis, the third engineer, and Mr. Heath, the fifth engineer.

The explosion took place, as already stated, on September 28, when the vessel was in the English Channel. The crown-plate of the combustion chamber collapsed without fracturing, and various nuts were drawn, with the result that there was a serious escape of steam by which, though no great material damage was done, four men lost their lives. Mr. Vaux then called witnesses, the first being Captain Young, the captain of the La Marguerite, who gave particulars of the occurrence. They anchored a few miles north-east of Dungeness, and the electric light went out, steam went down and the ship was helpless. At 10 o'clock p.m. a destroyer came alongside, which was fortunate as they had no electric light—they could not Morse—and the electricity had failed for the wireless. At great risk the destroyer launched a little dinghy, and sent two ambulance men on board. When they reached Dover, a medical man also came to the assistance of the injured. In cross-examination, witness said that he had never heard that the feed pumps did not work properly.

Mr. Albert Edward Laslett, engineer surveyor to the Board of Trade stationed at Liverpool, gave evidence to the effect that he surveyed the boilers on January 14, 1914, when he examined all the furnaces and combustion chambers, and saw no signs of deterioration in the plates. He considered that the pumps and boilers were in a satisfactory condition for the pressure under which they were intended to work, *i.e.*, 130 lb.

Mr. Alfred E. Coe, another Board of Trade surveyor, stated that he examined the safety valves and other fittings in December, 1914, and again in February, 1915. The water gauges were quite clear and in good working condition.

Mr. Arthur Tarrant, engineer surveyor to the Board of Trade, deposed to having held a preliminary inquiry in connection with the explosion on the arrival of the vessel in Southampton on October 4. He found that the crown-plate of the boiler had collapsed and some of the stays were broken; in addition to which the crown-plate was bulged between the stay-holes and the stays which were still intact. This pocketing of the plate had the effect of enlarging the stay-holes and making the stays slack. He examined all the girder stays and found them in good condition, but slack in the plate. The top plate of the starboard combustion chamber was locally bulged between the stays, and the girder stays were slack and showed signs of overheating. The boiler was in a fairly clean condition. He made an examination of the water-gauge connections and test-cocks, and found them all to be in a good condition and perfectly clear. In witness's opinion, the collapse of the crown-plate was brought about by recent overheating. From the condition of the boiler when he saw it, he did not think this could have existed previously, but the overheating was recent, and, in his opinion, was caused by shortness of water on the last voyage.

By Mr. Emanuel: Witness could not say how the shortness of water had occurred, but the engineers might possibly have been deceived in the height of the water, or that this particular boiler might not have been getting enough water. After the explosion all the boilers became short of water owing to the accident.

Mr. J. Fraser, superintendent engineer to the Liverpool and North Wales Steamship Company, gave evidence as to certain details, and referred to a complaint from Mr. McEwen, the chief engineer, shortly before the accident, as to the pumps not working properly. Witness had made an inspection of the collapsed boiler, and agreed with Mr. Tarrant in his views with regard to the cause of the explosion. He found very little scale, and had come to the conclusion that the cause of the explosion was overheating.

Mr. McEwen, chief engineer of the La Marguerite, in the course of his evidence, referred to difficulties experienced with the feed pumps during the voyage immediately preceding that on which the accident happened, and as to the steps he had taken to maintain the water in the boilers at the proper level.

After the examination of several other witnesses, Mr. Brierley, Borough Analyst of Southampton, deposed to having analysed pieces of scale found in the boilers; there was no trace of grease of any kind.

Mr. Joseph Ellis, third engineer, and Mr. J. E. Heath, fifth engineer, were among other witnesses who were called, it being stated that the fourth engineer was ill at the time. Both of these witnesses were questioned closely with regard to the condition of the feed pumps, water gauge, &c., and on the general question as to the shortness of water.

On the third day of the investigation, Mr. Edward Durbrow, the second engineer of the vessel, gave evidence. He had, he said, been at sea since 1887, and had held a first-class certificate for 25 years. On the previous voyage the feed pumps were working badly, and after the arrival of the ship at the port for which it was bound, he expressed the opinion to the chief engineer that she was not in a fit state to go to sea, the pumps not being fit to feed the boiler properly. Witness explained the steps taken before the explosion to satisfy himself with regard to the water levels, the pumps having been attended to previously.

Mr. T. R. Little, consulting engineer of the steamship company, also submitted to the Court various calculations dealing with the rate of diminution of the water in the boilers under various circumstances.

The examination of witnesses having been concluded, Mr. Vaux addressed the Commissioners and submitted the following questions for their decision:—

1. Was the working and management of the boiler which exploded entrusted by the owners to competent persons?

2. At the time of leaving Dover on the evening of September 28 last (*a*) was the crown-plate of the port combustion chamber of the after starboard boiler on board La Marguerite in good condition, and fit for the pressure at which the boiler was worked; (*b*) were the mountings of the said boiler in good working order; (*c*) were the feed pumps in good working order?

3. After leaving Dover on September 28 last were proper measures taken by the chief, second, third and fifth engineers to ensure that a proper level of water was maintained in the after starboard boiler?

4. What was the cause of the collapse of the crown-plate of the port combustion chamber of the after starboard boiler at or about 6.50 p.m. on September 28 last?

5. Are the Liverpool and North Wales Steamship Company, Limited; Mr. Joseph Fraser, their superintendent engineer; Mr. William McEwen, the chief engineer; Mr. Edward Durbrow, second engineer; Mr. Joseph Ellis, third engineer; and Mr. John Edward Heath, fifth engineer of the ship; or is any, and which of them, to blame for the explosion. Should any, and which of them, pay any, and what part, of the costs of this formal investigation?

Mr. Hudson, the presiding Commissioner, in delivering judgment, said the boilers on board La Marguerite were built under the Board of Trade survey, and in accordance with plans prepared by Mr. Little, the consulting engineer to the owners, and further, they were periodically surveyed by Board of Trade surveyors as well as by the superintendent engineer to the owners. The Commissioners were satisfied that no damage was done to the boilers of the vessel on the voyage previous to that on which the explosion occurred. In connection with the circumstances of the explosion, he said that the Commissioners were chiefly concerned with Messrs. Durbrow and Heath, and with what they each said they did as to watching the water gauges, regulating the supply of water, &c. No one had suggested any explanation of the explosion other than that it was due to overheating from shortness of water, yet, if they were to believe the evidence of the two engineers named, it could not possibly have happened, because they said there was ample water in the boilers immediately before the explosion, and that nothing occurred to have given rise to shortness of water. There was no missing link in the chain of evidence of these two men to negative the cause of overheating through shortness of water, though that was the admitted cause of the explosion. The Commissioners were satisfied that Mr. Heath, the fifth engineer, was not a witness whose evidence could be relied on, and with regard to Mr. Durbrow, though he gave his evidence with more apparent frankness, they could not help thinking that the two men must have put their heads together to tell an impossible story. The only question the court had to decide was, whether the blowing down of the boilers and opening and closing the check valves was carried out, and it was quite clear that it was not. They were satisfied that the real cause of the explosion was that when the after starboard boiler was blown down, the water was lowered too much, probably as low as the crown of the combustion chamber, and that neither Mr. Durbrow nor Mr. Heath looked in to see how much the water had been lowered. It was clear that neither grease in the water nor scale on the plates existed or caused the explosion. With regard to the question of responsibility, the Commissioners did not consider that the owners were in any way responsible; they had employed competent advisers in Mr. Little, their consulting engineer, Mr. Fraser, the superintendent engineer, and Mr. McEwen, chief engineer. Mr. Fraser was not in any way to blame, nor was Mr. McEwen, who seemed to be a thoroughly competent and zealous engineer. The Commissioners considered that Messrs. Durbrow and Heath were jointly responsible for the explosion; they were working together in carrying out the blowing down of the boilers, and in regulating the check valves, Mr. Durbrow undertaking the former duty and Mr. Heath the latter, but, as Mr. Durbrow had said, they both knew what the other was doing.

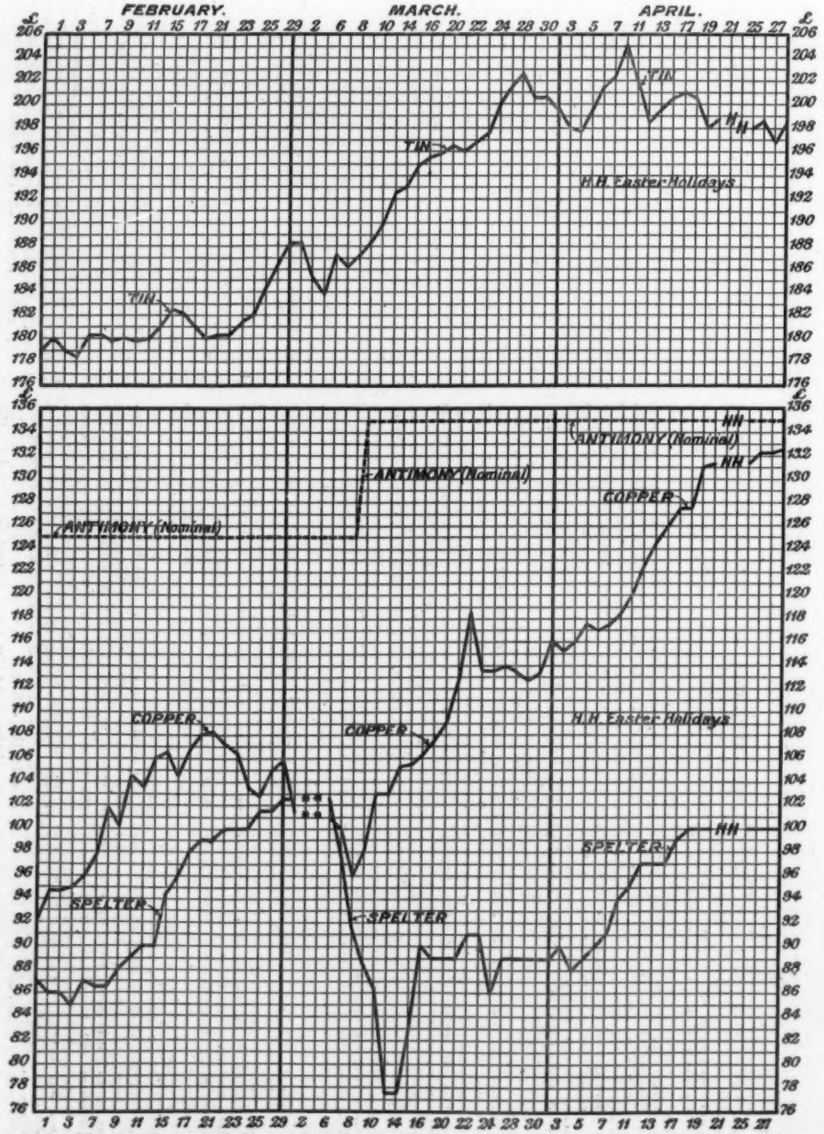
Mr. Hudson dealt fully with the various questions put on behalf of the Board of Trade, and said that the court found that the working of the boiler was entrusted to competent persons; that on leaving port on the evening of the explosion the crown-plate of the port combustion chamber of the after starboard boiler was in good condition, as were the mountings and feed pumps, and that the cause of the collapse was overheating through shortness of water. Messrs. Durbrow and Heath were responsible and were to blame for the explosion, and the Court ordered that Mr. Durbrow should pay the sum of 30*l.*, and Mr. Heath 20*l.* to the Board of Trade towards the costs and expenses of the investigation.

In closing the inquiry, the Commissioners expressed their deep regret at the loss of life, and their sympathy with the bereaved families.

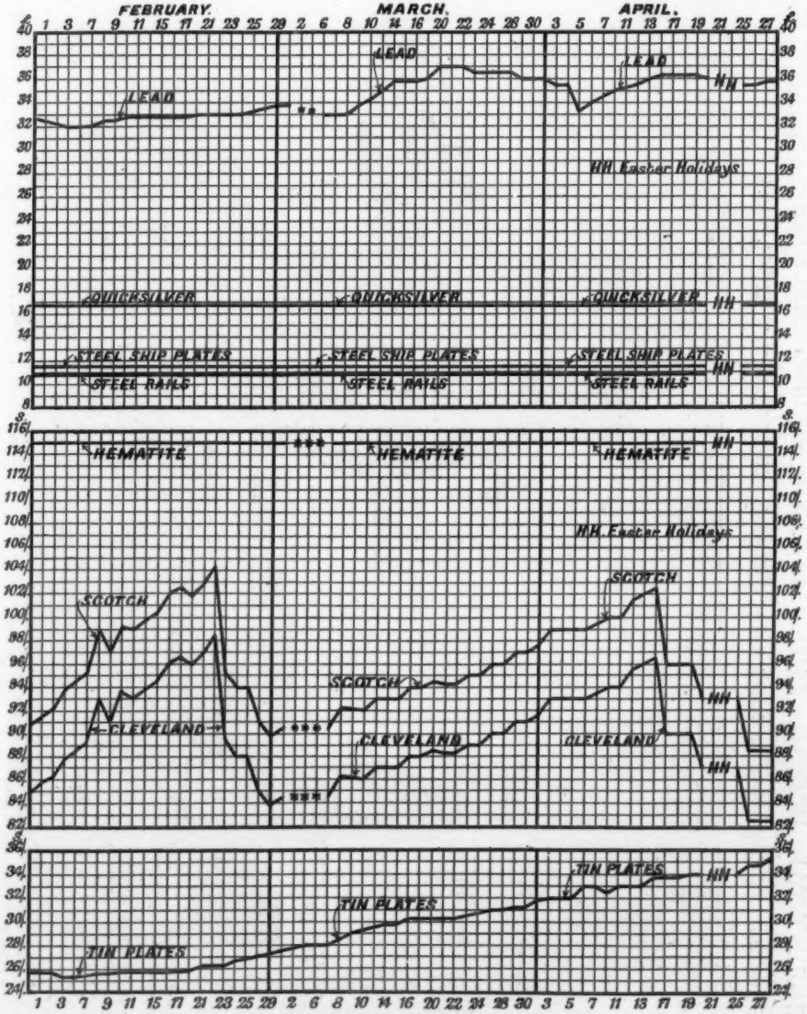
AMERICAN TRADE WITH AUSTRALIA.—Prof. Phillip B. Kennedy, Director of the Department of Trade and Transportation at New York University School of Commerce, has been appointed Commercial Attaché from the United States to Melbourne. The main object of Mr. Kennedy's work will be to foster a friendly spirit between the United States and Australia, and to help as much as possible to keep the commercial relations on a sound footing. Speaking to a Press representative, Mr. Kennedy expressed the view that the United States was exceedingly friendly to Australia. America had watched Australia's part in the war with the greatest admiration, and had taken much interest in her national schemes, particularly in the training of cadets, which he believed would be copied in the United States.

THE LATE MR. FREDERICK WALKER.—We regret to learn of the death of Mr. Frederick Walker, who was well known as the author of several works on engineering, and as a consulting engineer and patent agent. Born at Charlton, Kent, in 1853, he served an apprenticeship of seven years as a millwright, gaining further experience at the works of Mr. Bryan Donkin and of Messrs. Easton and Anderson, and continued afterwards for some time as a seagoing engineer in P. and O. liners. Later he took up the business of consulting engineer and patent agent. Amongst the works on which he was engaged was the installing of electric light on the Suez Canal, and the designing, along with the late Mr. Anthony Reckenzaun, of the first electric launch to cross the Channel (the Volta). He was the inventor, in 1881, of the first electric dry battery, and in 1880 was closely identified with the "Jarman" electric road cars. He contributed to the technical Press, and was the author of several important works, amongst them one, published six years ago, on aerial navigation; others were on practical dynamo building, tables and memoranda for electrical engineers, electricity in the engine room, and the design and equipment of launches. Failing health necessitated his retirement some time ago, since when he had lived at Cheltenham, where he died on April 8, and is survived by his widow and two married daughters.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.



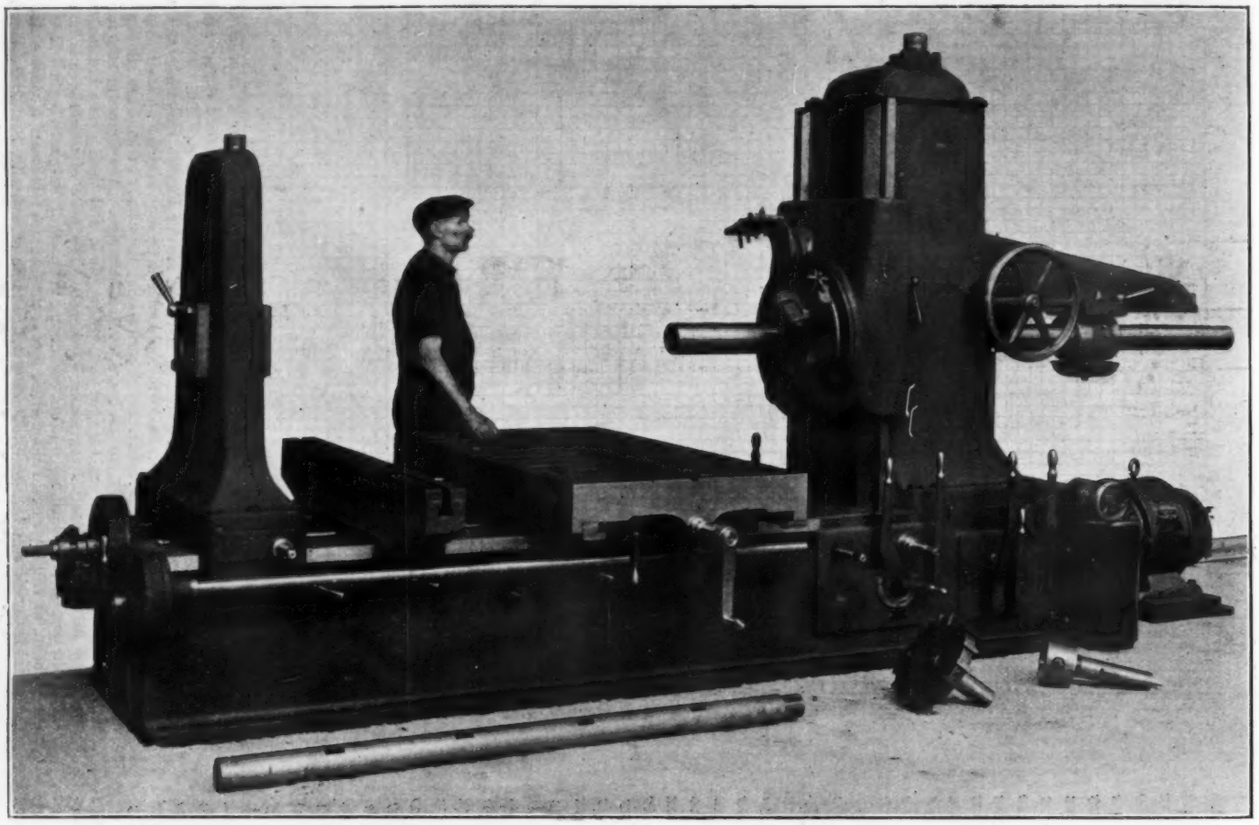
* On March 1 last an Order made under the Defence of the Realm Act prohibiting speculative dealings in copper, antimony, spelter, lead, iron, and other metals required for war work, was published in the *London Gazette*. In consequence of this order business in these metals was suspended on the London Metal Exchange, and also on the Glasgow Pig-Iron Warrant Market, on the following day. The order, however, was not intended to restrict legitimate trading, and business of this kind was therefore resumed in London on March 6 and in Glasgow on March 7.



NOTE.—In the diagrams on the present page the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for "fine foreign" and "standard" metal respectively. The prices plotted for antimony and lead are for English metal in both cases, while those for spelter are for American metal—the only kind at present available. Steel ship-plates and heavy steel rails are plotted to Middlesbrough quotations; the usual discounts are allowed in the case of ship-plates, but rails are net, free on board, at Middlesbrough. The figures plotted for hematite, Scotch, and Cleveland irons are Glasgow settlement prices, and these prices are per ton, as are also those for all other metals previously mentioned. The price of quicksilver is however, per bottle, the contents of which weigh about 80 lb., and the price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market day, and the horizontal lines represent 1*l.* each in all cases, except those of hematite, Scotch and Cleveland irons and tin plates, where they represent 1*s.* each.

HORIZONTAL BORING, DRILLING, AND MILLING MACHINE.

CONSTRUCTED BY THE NILES-BEMENT-POND COMPANY, ENGINEERS, NEW YORK, U.S.A.



WE illustrate above a horizontal boring, drilling, and milling-machine now being manufactured by the Niles-Bement-Pond Company, of Trinity Building, 111, Broadway, New York, U.S.A. One of the special points of this tool is that all its movements can be controlled from either side of the machine, as two complete sets of operating levers are provided. It will also be noticed that the spindle saddle is located centrally in the column, instead of being mounted on one side, as is usually the case in machines of this type. This feature of the design allows the whole of the parts to be arranged symmetrically about the spindle axis, and has other advantages which will be referred to later.

The bed of the machine is a cored-out box-casting designed to give maximum strength and rigidity, so that no special foundation is required. It is entirely closed in at the top to prevent chips from falling inside. The driving, feed, and traverse gears are placed inside the bed, but are easily accessible by removing large cover-plates, which are provided on both sides of the bed. The driving gears run in an oil bath, and the feed and traverse gears are lubricated on the splash system. The main column is of box form, open through the centre, but connected at the bottom in one continuous casting. The two parts thus formed are connected at their upper ends by a cap, tongued and grooved to the main casting, so that a very rigid structure results. Strengthening ribs, suitably located for resisting bending and torsional stresses, are provided inside the column casting. The spindle saddle slides on V-tracks planed on the front faces of the column. These tracks, it should be mentioned, have unequal sides, those on the outer sides being broad to give a large bearing surface for the saddle, and those on the inner sides being approximately at right angles to the others in order to resist side thrusts. It will be seen that this design of saddle-bearing gives an excellent method of maintaining the spindle alignment, both when the saddle is clamped for boring and when it is sliding vertically for milling. Another important point is that the heavy back pressure due to boring tends to increase the accuracy of alignment instead of distorting the whole column, as is the case with the usual construction. The saddle has vertical power feeds for milling and a rapid power traverse, both of which are operated by a vertical screw. This screw is connected by gearing to a similar screw in the outboard column, which carries the outer bearing for the spindle, so that the saddle and outer bearing always move in unison. The spindle, which is 4¼ in. in diameter, is made of high carbon steel, finished by grinding. It slides in a long sleeve, which runs in removable bearings, and is driven by two large spline keys set in the sleeve and engaging with keyways cut in the spindle. The driving gear is enclosed in the saddle with a portion extending forwards and exposed so that it can be used as a face-plate. The main bearing for the sleeve is tapered, to enable it to be adjusted to take up wear. The feed and rapid traverse movements of the spindle are obtained by means of a screw mounted in a backward extension of the saddle, as clearly shown in the illustration. The feed is suitable for boring or drilling, and a total movement of 60 in. can be obtained in two shifts of 30 in. each. These, and all other feeds on the machine, have six variations and are reversible. The spindle speed can be varied from 5 to 150 revolutions per minute without affecting the amount of feed per revolution.

The outboard column, it will be noticed, is made in two parts, of which the lower is gibbed to the bed and is adjustable along it. The upper part is bolted and dowelled to the lower part, so that the former can be removed to accommodate long pieces of work and easily replaced in correct alignment. The screw carrying the bearing can be disconnected from the rest of the mechanism, so that the remainder of the gearing need not be dismantled when the upper part of the column is removed. The table, which is provided with the slots for holding the work, has a working surface 60 in. long and 33 in. wide. It is provided with power cross-feeds for milling and rapid power traverse for quick adjustment, the total movement in this direction being 48 in. The table is mounted on a saddle which is of sufficient length to support the table at the extreme ends of its travel. The saddle is adjustable along the bed by hand or by power, the movement being obtained by a screw placed centrally between the tracks of the bed. The saddle is gibbed to the bed with square locks adjustable for wear, and the table is attached to the saddle in a similar manner. The maximum height of the centre line of the spindle above the table is 30 in., and the maximum distance between the face-plate and the outer bearing of the spindle is 7 ft. If desired, a round table with automatic circular-feed motion can be supplied, and an additional work-support can be provided if necessary. The latter device is fitted on the machine illustrated, and will be seen to consist of a comparatively narrow casting, of the same height as the main table, provided with a tee slot in its upper surface for fixing the work; it can be clamped in any position on the bed. The machine illustrated is also equipped with a facing head, which may either be attached to the face-plate gear or fastened on to the boring-bar. This device is provided with automatic radial feeds operated by a screw carrying a star-wheel, which engages with adjustable fingers as the face-plate rotates; an inspection of the illustration will make this clear. The illustration also shows in the foreground a boring-bar, milling-cutter, and bell-chuck, the latter being used for driving boring-bars not provided with tapered shanks.

The machine is usually driven by a 10-horse-power direct-current variable-speed motor having a 3 to 1 speed range, or by a four-speed alternating-current motor. It may also be driven by a cone pulley and countershaft, or by a single pulley and gear-box; a gear-box would also be employed with a constant-speed alternating-current motor. The machine is adapted for work requiring great accuracy, and is also suitable for heavy boring. It is entirely free from all delicate parts, so that it appears to be a very durable tool as well as a serviceable one. The London offices of the Company are at 25, Victoria-street, Westminster, S.W.

AUSTRALIANS TO LEARN SUBMARINE-BUILDING.—The Australian Minister for the Navy has selected a number of candidates desirous of proceeding to England for instruction in the building of submarines, in order that they may be able to take up this work in the Australian Naval yards.

SHIPYARD CRANES OF THE ROTTERDAM DOCKYARD COMPANY.*

By M. G. DE GELDER, Member.

ALTHOUGH several papers on shipyard cranes have been read before this Institution in previous years, I hope that the following description and particulars of shipyard cranes introduced by the Rotterdam Dockyard Company may be of some interest in connection with the development of hoisting appliances for shipbuilding purposes. The Company was established in 1902, and in 1904 started on the New Waterway its repairing works, which included well-equipped engine and boiler shops, foundry, smithy, &c., adjacent to the ship-repairing sheds, and two private floating docks. In 1906 it was decided to build a sea-going steamer of 1600 tons dead weight, and as the appliances for the building of new vessels have been steadily and rapidly improved during the intervening years, the Rotterdam Dockyard Company is now turning out more tonnage than any other shipbuilding yard in Holland, the output last year having been nine steamers, each of 6000 tons dead weight or over, complete with all machinery. Originally the shipyard used the ordinary derrick masts of modernised type (viz., latticework masts with electric hoisting winches on the ground level), and, in addition, wire-rope switchbacks between wooden poles placed at the ends of each berth. This combination of derrick masts and switchback was found to be very satisfactory when account was taken of the low initial cost, but it was thought advisable to adopt a more efficient arrangement, because the size of steamers to be built was constantly growing, and quick handling of material was absolutely necessary in order to arrive at a large output with the limited number of workmen available in the Rotterdam port.

Fig. 1.

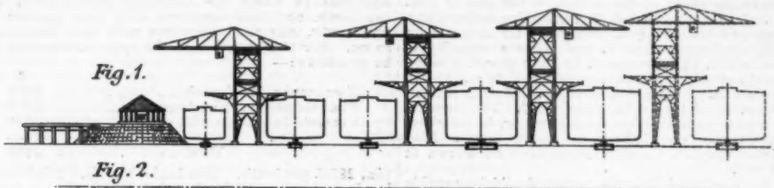
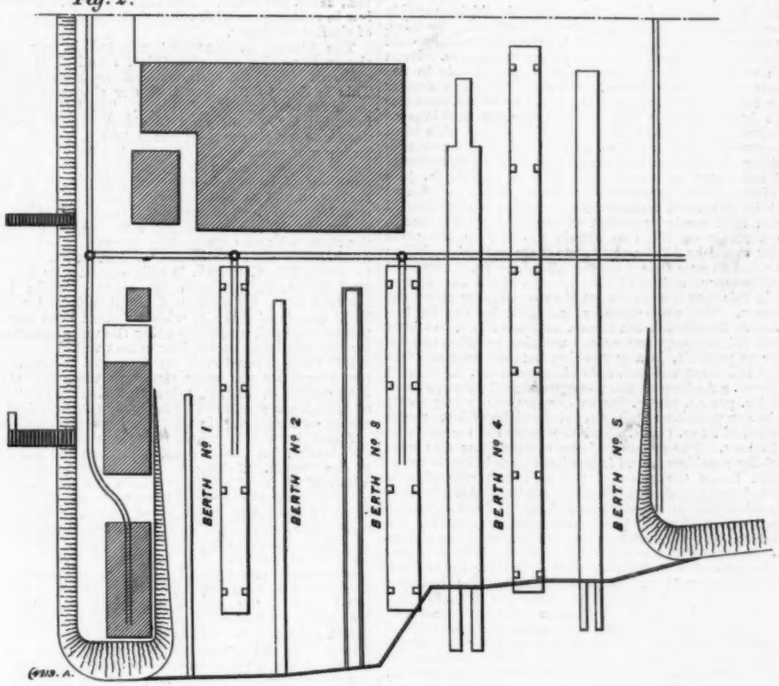


Fig. 2.



Various systems of shipyard cranes are already in use, and in the papers read on this subject interesting particulars have been published regarding them. In some of the larger British and German shipyards overhead cranes, very common in engineering and boiler works, have been adopted, combined with roofed building sheds, the cost of which may amount to from 25,000*l.* to 50,000*l.* for each berth. It is doubtful whether such high initial cost will give an adequate return, but I think it would only be possible in exceptional cases, such as in the building of huge and expensive Atlantic liners, large battleships, &c. On the other hand, many British yards capable of efficient work with regard both to price and time of delivery are still adhering to the system of derrick masts already referred to, and even now large battleships are being built by means of such hoisting appliances. In view of these facts shipbuilders are obliged to study the problem carefully before taking a decision as to the system of shipyard cranes to be fitted. Generally speaking, I have the impression that the necessity for the quick handling of material has often led to arrangements being adopted which are too expensive from an economical point of view, while, on the other hand, conservatism or want of capital has made several shipyards adhere too long to old-fashioned methods of building vessels as far as cranes are concerned.

It is, of course, rather difficult to design a satisfactory arrangement between the two extremes referred to. In this respect each shipbuilder should be guided by his own personal views or experience, by special requirements and local circumstances. As a rule, any modern arrangement of shipyard cranes will lead to wider spacing of the building berths than ordinary derrick masts would require. It is often claimed as an important advantage of such derrick masts fitted between the uprights that they do not take up much space. It is doubtful, however, whether nowadays a large number of narrow-spaced berths really are an essential advantage. I rather think the time has passed when it was considered a wise policy to lay down the vessels as close as possible to each other, so as to get the maximum number of berths on a certain length of river frontage. The amount of money wasted owing to want of space is not always realised, for surely in modern industrial works plenty of clear ground means a good deal of saving. From an economical point of view it may be better to build eight steamers per year on three berths than to turn out the same number of vessels on four berths, laid down more closely on the same ground space. Therefore, even if the fitting of shipyard cranes requires a strip of ground to be left open between the berths, thereby reducing the number of berths possible over a certain river frontage, it does not follow that valuable ground is really lost.

It must be borne in mind that ship material cannot always be put in place immediately when ready for erection. Every shipbuilder now tries to rivet mechanically on the ground as many floors, brackets, girders, bulkheads, &c., as possible to avoid the expense and delay due to riveting up after erection. Apart from this, on account of the laying-off system now adopted more and more in Continental yards, large numbers of deck, shell, and double-bottom plates, &c., are punched and machined before the keel of a vessel is actually laid. Under these circumstances large quantities of ready material have to be removed from the shops to somewhere in the yard near the building berth before being put up in position. To avoid shifting such material more than once sufficient ground space must be available either in front of or between the berths. As it is always cheaper to transport material by trucks alongside the berth (on which it is already loaded) than by cranes over the top of the vessel, open ground space alongside the berth is certainly useful. On the other hand, ground space is kept available in most yards in front of the berths in anticipation of the building of larger ships in the future. Under these circumstances it seems advisable to design the shipyard cranes in such a manner that they can lift

FIG. 3.

* Paper read before the Institution of Naval Architects, April 13, 1916.

material as well from the ground in front as from alongside the ships, and so that they can deposit this material without further handling to the position where it is to be fitted.

In this respect derricks or masts, forming fixed electric tower cranes, as, for instance, those described by Mr. Piaggio in the Transactions for 1907,* are quite unsatisfactory. Referring to the discussion on this paper, I simply wish to point out, firstly, that to avoid more than one lift of material when ready, it has to be transported at once in way of the crane overreaching the part of the vessel where such material is to be fitted, which in practice may often cause much trouble; secondly, that if such cranes are used alternatively for two berths next to these cranes, the ground space which must be kept open between the two berths for the material referred to reduces the working radius of the cranes on one side by at least the width of this open ground space; thirdly, that several cranes overlapping each other are necessary to enable the cranes to bring the material to the part of the ship where it is required. For two berths for vessels of about 360 ft. length four cranes with long jibs would have to be fitted, and as the price of each crane, when capable of lifting, for instance, 3 tons at the outer end of the arm, will cost at least 2000*l.*, including foundation, an outlay of 8000*l.* would be required for such an arrangement, which would be still far from satisfactory.

Although such cranes have been fitted in several yards, the idea of adopting this principle, in our case, was rejected at once on account of the above considerations. Complete plans and estimates were, however, made for overhead travelling cranes not roofed over, running on top of steel structures, and covering not only the full width of the berth, but also 20 ft. of ground space reserved for depositing material alongside the berth. On account of the great width of the cranes consequently required, and the excessive height necessary for the girders to enable the cranes to pass over the highest point of the vessel at any state of building, the cost of this arrangement was found to be much in excess of the cost of cranes as finally adopted, apart altogether from the fact that the overhead cranes did not appear to be more efficient.

The travelling cranes of the hammer type, viz., transportable tower cranes running alongside the berths as described in Mr. Murray's paper in the Transactions of 1906,† were also considered, but found not quite suitable. In the first place, the berths of our shipyard are purposely made sloping over a distance of about 300 ft. from the ordinary low-water level on the river side up to the ground level of the shops, which is above the highest spring tide, *i.e.*, 13 ft. above ordinary low water, so as to reduce the height of the keel-blocks at the fore-end of the vessels building. On this sloping part the tower cranes could not travel safely if the rails were simply laid on the ground.

Apart from this, I rather fear that, although it is not impossible, it is always very troublesome in a shipyard, to keep the rails and the ground space sufficiently clear of obstructions for the safe running of such cranes, more especially if this ground space is used for depositing material, and if the cranes are handled from a cabin which is about 60 ft. above the ground. Finally, the weight of such cranes, when of sufficient dimensions and capacity, is about 80 to 100 tons. The weights to be handled by these cranes are mostly only 1 to 2 tons, and it is not economical to have such heavy cranes constantly running for shifting light material. It must also be expected that these cranes will in practice never travel along the berths with the speed they are designed for, as already pointed out by Mr. Saxton White, when discussing Mr. Murray's paper. In this respect the cantilever cranes also mentioned by Mr. Murray, and more fully described in Mr. Fairburn's paper in the Transactions of 1902,‡ are more satisfactory; but it must be a serious disadvantage of this system, much favoured in America, that the loads can only be shifted either in a longitudinal or a transverse direction, so that it is necessary to shift the entire crane for the slightest adjustment in the position of the material which has to be put in place. Besides, the weight of the crane is increased by the arm used for the adjoining berth without it being possible to use the two arms simultaneously.

The above considerations have guided me in designing a system of shipyard cranes, which may be considered a combination of the ideas embodied in the travelling tower crane and the cantilever crane. As far as I know, this system has not been previously adopted in other shipyards, and in any case not on a large scale. I consequently have taken the liberty to submit to the Institution a description of it, with particulars of the actual cost of these cranes and the actual results obtained during the first year of use. For the construction of these cranes I refer to the illustrations (Figs. 5 to 7 on the two-page plate), the general arrangement plan (Figs. 1 and 2 on the preceding page), the crane plan, and the plan of the steel structure (Figs. 8 to 10 on the two-page Plate).

The cranes, supplied by the Haarlemsche Machinefabriek, of Haarlem, are of the all-round swinging type, and run alongside the berths on top of lattice girders supported by columns. The cranes can lift 3 tons at the extreme end of the arm, *i.e.*, with a radius of 22 m. (72 ft.) from the centre, 7½ tons with a radius of 9 m. (29 ft. 6 in.), and intermediate weights between these limits. These intermediate weights, for instance, 5 tons at a radius of 13.5 m. (44 ft. 3½ in.) are painted on the arms at the corresponding radius, and in the cabin of the operator a special ampere-meter is placed marking the weight lifted (instead of the amperes used), so that the operator may notice at a glance whether it is safe to lift a certain load at the required radius. This safety check was considered necessary, as ordinary shipyard men are often far out when estimating weights of certain material to be lifted. The cranes were tested with 10 per cent. overload. The hoisting speed is ¼ m. (20 in.) per sec. for 3 tons, ½ m. (13 in.) for 5 tons, and ¼ m. (10 in.) for a load of 7½ tons. The horizontal travelling speed is 1 m. (39 in.) per sec., and the swinging of the crane through 360 deg. requires only 35 secs. The travelling speed of the trolley on the arm is ¼ m. (20 in.). The motors for hoisting, travelling horizontally, swinging and traversing of trolley are all designed for 440-volt continuous current, and have a capacity of 27 horse-power, 15 horse-power, 15 horse-power, 4 horse-power respectively. The crane gauge is 6.25 m. (21 ft.), and the weight of the unloaded crane, including ballast, is 34 tons, equal to 8.5 tons per wheel. The pressure of the wheels on the girders may, however, be considerably increased by the wind pressure on the cranes. Plan and elevations of the cranes themselves are shown in Figs. 5 to 7.

We have assumed that the cranes should be capable of working with a wind pressure not exceeding 50 kilos. per sq. metre (10 lbs. per sq. ft.), as heavy storms would make it in any case impossible to use the cranes. Even with such a wind pressure it is not practicable to use cranes of any description, owing to the great danger with the material swinging about. The wheel pressures have been carefully calculated in various positions of the crane, with the maximum load combined with wind pressure of 50 kilos. per sq. metre, and also in a certain position of the unloaded crane with a wind pressure of 200 kilos. per sq. metre, viz., 40 lbs. per sq. ft. (the maximum which may possibly be expected). We found that in the most unfavourable position of the loaded crane, with a wind pressure of 50 kilos. per sq. metre, the pressure on the two wheels running on the same girder would be 11.5 and 17.6 tons respectively. When the wind pressure rises to 200 kilos. per sq. metre, the wheel pressure will be 17 tons on each of the two wheels, but in this case the cranes are always standing above the columns. The steel structure supplied by the Rotterdamsche Machinefabriek Braat, at Rotterdam, has been calculated to carry two cranes working as close to each other as possible, in any position between two columns under the most unfavourable circumstances, as referred to above. As long as the wind pressure does not exceed 50 kilos. per sq. metre, the two cranes can consequently lift in any position required a total weight of 6 tons with a radius of 22 m. (72 ft.), and at smaller radii weights up to 15 tons. The spacing of the columns has also been carefully considered, and it has been found that between certain limits the price of the structure was slightly affected merely by modifying the spacing. As, of course it is advisable to avoid obstructions by fixed columns, a spacing of 27 m. (88 ft.) was finally chosen for the columns. For the smaller ships the length of the girders was consequently made $3 \times 27 = 81$ m. (266 ft.), plus two lengths of 5 m. (16 ft.), each projecting beyond the end columns, or 91 m. (298 ft.) in total, and for the larger ships $5 \times 27 = 135$ m. (443 ft.) plus 2×5 m. (16 ft.), or 145 m. (475 ft.) in all. Taking into account the length of the crane arms, when they extend beyond the ends of the girder path, there is a length respectively of about 127 m. (418 ft.) and 181 m. (593 ft.) within reach of the cranes. The arms of 22 m. working radius project 19 m. (63 ft.) outside the columns. Allowing 9 ft. for the uprights and free space between shell and uprights, the crane on the shortest girder can entirely overreach a vessel of about 370 ft. in length and 54 ft. in width, or, say, of 6300 tons dead weight. Even a wider vessel could be built by placing the uprights under the steel structure, but this would interfere with the transport of material below this structure, which is not advisable, as the arrangement has been designed in such a manner that the material can be lifted both from top and bottom ends of the girders, also from alongside the berth and between the structure. For this purpose ordinary railways are laid on the ground space below the structure and the columns are arched so as to allow trucks and locomotive cranes to pass underneath. These arched columns are placed on reinforced concrete foundations. Of course these foundations had to be calculated to suit the important moments which may occur. With reference to these I may mention that under the most unfavourable conditions the pressures on the feet of both parts of the arched column were found to be 157 and 7 tons respectively, corresponding to a maximum moment of 156 m.-tons (500 ft.-tons). The nature of the soil on which the columns are placed allowed us to design the foundation in such a manner that we could dispense with any piling (which is, as a rule, required in Holland for all foundations).

The shipbuilding material can be hoisted between the two vertical girders, as shown on the two-page plate, and for this purpose the sloping parts inside the girders (formed by the horizontal stiffeners required for wind pressure) are protected by half-round irons, to prevent the plates catching the girders.

If two cranes are running on the same girder, it is essential that the railway on the ground space should extend at least about half-way down the berths, so as to avoid the one crane interfering with the working of the other. In this case the crane on the riverside is, of course, to be used chiefly for the after part of the vessel, and the material for this part must be deposited as far down the berth as possible. To discharge such material from the trucks small hand cranes have been fitted on the columns of the steel structure, the hoisting ropes of which can be worked by electric winches fitted between the berths. Up to the present these hand cranes have practically never been used, as the electric shipyard cranes have had time available for discharging trucks also.

We found after a year's experience that one crane as described is quite sufficient to transport all the material required for the building of a 6000-ton steamer, about 360 ft. long, and that such a steamer can be launched practically complete for delivery, including masts, winches, &c., within four months after laying the keel; this compares favourably with any foreign records. To build two such steamers simultaneously on two adjoining berths, one steel structure with two cranes would be quite sufficient. If a yard had to be laid out for building steamers of this size only, it would consequently be advisable to adopt the following arrangement, viz., *one* berth, one steel structure with two cranes; for *two* berths, one steel structure with two cranes, and so on. For two such berths the approximate cost will be as follows:—

	£
Two cranes, 1500*l.* each	3000
Steel structure (91 m. long)	2250
Concrete foundations for same	500
Total	5750

viz., 2875*l.* per berth. This initial cost is, I think, fairly low in comparison with other systems of shipyard cranes of similar efficiency.

The general arrangement adopted in our yard, as shown in section and plan (Figs. 1 and 2), is somewhat different from the arrangement as suggested above. This is due to the fact that our shipyard berths are made for various sizes of vessels. The left-hand berth is intended for steamers up to about 275 ft. length, the next one for steamers of about 360 ft. length. As the building of small steamers is not in our line, unless thay are of the fast passenger steamer type (for which quick handling of large quantities of material is of less importance), and as consequently this small berth is often used for the deposit of material instead of for the building of vessels, it was considered sufficient to fit one steel structure with one crane only between No. 1 and No. 2 berth. The next berth, No. 3, designed for vessels up to about 375 ft. length, is fully covered by the second steel structure, also with one crane. Berths 4 and 5 are laid down for vessels of about 550 ft. length. To build vessels of this size within a short time two cranes will be required, and when using the same steel structure for two adjoining berths four cranes would be necessary. While there is practically no chance of obstruction with two cranes on the same structure when the structure is about 480 ft. long, it is doubtful whether the efficiency of the cranes would not be seriously compromised if four cranes were running simultaneously on such a girder.

Apart from this, when using a single structure for two berths, the cranes must overreach the full breadth of the vessels. Taking into consideration the possible width of 70 ft. of steamers which are 550 ft. long, the arms of such cranes would have to be much longer than those of the crane as described above. The weight of such cranes and of the steel structure would have to be increased considerably, and the cranes would be more difficult to handle. For this larger type of vessel I consequently preferred to adopt the arrangement of a steel structure next to each berth, as shown on the right-hand part of the section (on which the dotted lines indicate the steel structure still to be built when No. 6 berth, intended for vessels of 650 ft. long, comes to be used), with two cranes (or eventually three for No. 6 berth) of the type as described above, running on the same structure. These cranes will not fully overreach the vessel's berth, but of course the part of the ship not covered by the cranes of the one structure will be covered by the cranes of the next structure, as the cranes of the two adjoining structures will then overlap each other. With reference to this overlapping, it is advisable to make the cranes on different structures of different heights above the ground level. The height of the various crane-hooks, arranged to suit the size of the vessels to be built on the various berths, is as follows, measured from the lowest part of the berths (which, as mentioned before, is 4 m. lower than the ground level at its highest part, so that the height of the columns supporting the steel girders is gradually reduced towards the fore part of the vessels, the crane rails being, of course, kept horizontal):—

Top of rail, first structure ...	19 m. (62 ft.)
Crane-hook above rail	5 m. (16 ft.)
Total ...	24 m. (78 ft.)
Top of rail, second structure ...	22 m. (72 ft.)
Crane-hook above rail	7 m. (23 ft.)
Total ...	29 m. (95 ft.)
Top of rail, third structure ...	22 m. (72 ft.)
Crane-hook above rail	9 m. (30 ft.)
Total ...	31 m. (102 ft.)
Top of rail, fourth structure (not yet built)	25 m. (82 ft.)
Crane-hook above rail	9 m. (30 ft.)
Total ...	34 m. (112 ft.)

Of course it may be possible that this height would not be above the highest point of the vessel on the berth, especially of large passenger ships; but it is not absolutely necessary that the highest parts of light superstructures should be erected by the cranes, and, generally speaking, the height referred to will be sufficient for all practical purposes. It would not seriously affect the price to increase the height of the cranes, but for the sake of easy handling I think it is inadvisable to make the crane heavier than is absolutely necessary.

We have had a fair opportunity of ascertaining the direct saving in wages due to the shipyard cranes, by

* See Trans., I.N.A., vol. xliv., page 114. ENGINEERING, vol. lxxxiii., pages 412, 484.

† Trans., I.N.A., vol. xlviii., page 179. ENGINEERING, vol. lxxxi., pages 483, 509.

‡ Trans. I.N.A., vol. xliv., page 229.

building two sister vessels of about 6000 tons on the same berth and under exactly the same circumstances, with this difference only, that the first ship was built previous to fitting the cranes, and the second ship immediately after. The direct saving obtained by reducing the piecework rates of the ironworkers and labourers, *i.e.*, exclusive of riveters, joiners, carpenters, smiths, and painters, amounted to 6 per cent. At first sight this saving may not look very important, but, of course, apart from this direct saving there are indirect savings which are rather difficult to estimate. The cost of upkeep of wires, blocks, tackles, &c., is practically reduced to nothing. Although the piecework rates for riveting are not changed, the cost of riveting is reduced on account of the fact that the cranes allow parts of bulkheads, girders, &c., to be riveted up hydraulically on the ground before being lifted in place, instead of being riveted up by hand or pneumatically after erection in place. Another important factor is that the engineers can now put in place all their auxiliaries and shafting previous to the vessel being launched, thus obviating great delay and inconvenience in completing the vessels at the finishing berth.

Finally, there is the important saving in time of building. For the 6000-ton vessels referred to above, built under similar circumstances, the time for the second ship was reduced from five to four months, which means an increase of output of 25 per cent. and a considerable reduction of the amount of the general expenses to be charged up to each vessel, apart from the fact that the time of delivery which may be quoted often affects the contract price which may be obtained.

As an actual fact, it may be mentioned that within 18 ordinary working days after the first keel-plate was laid down, all the remaining keel-plates, the bottom plating in way of double bottom, the entire double bottom, including centre girder, intercostal floors, margin plates, tank top plating, all the frames from collision bulkhead to after peak bulkhead, two complete side stringers, and all bulkhead wing plates, also 60 shell-plates, and various strong beams, all for a 6200-ton deadweight cargo steamer, have been erected in place by the use of two cranes as described above.

As a practical result of the increased output due to the shipyard cranes, the pneumatic and hydraulic riveting plant had to be enlarged, additional shipyard machines and frame-bending furnaces had to be added, and, finally, the engineering department, which had previously been always ahead of the shipbuilding department with reference to delivery, required a good many new machines to keep pace with the shipbuilding after the installation of the cranes. These extra requirements of practically all the branches of the works afford the best evidence of the efficiency of the shipyard cranes. This, in itself, is very satisfactory, but it clearly proves that when making an important improvement in a certain branch of his works a manager cannot reap the full benefits unless he can also afford the additional expense of the consequential improvements required in all the other branches.

THE APPLICATION OF SCIENCE IN FACTORIES.*

By Sir WILLIAM BEARDMORE, Bart.

(*Presidential Address to the Iron and Steel Institute.*)

THE pleasure I realise in the great honour you have conferred upon me is overshadowed by the reflection that our departed friend, Dr. Greiner, my predecessor, is not with us, as, under happier circumstances, he might well have been, to introduce me as your President. By his death, as in his life, he embodied and exemplified all the finest characteristics of a noble race. In this way there is brought home to us to-day, with poignant directness, the great sacrifices made by Belgium, as well as by our other gallant and courageous Allies. Belgium willingly accepted the fate that destiny imposed in taking the first blows of the intentionally aggressive and unscrupulously inhuman attack upon life, liberty, and law—individual, national, and international. The stoppage of the principal departments of those magnificent Cockerill works which Dr. Greiner had done so much throughout his lifetime to make a high example of scientific and economic efficiency must have been to him almost as great a trial as the terrible ravages among his people and in his country. That it hastened his end there can be no reasonable doubt. But triumphant over death and destruction is the dominant and everlasting influence of the soul of the man and of the people. Through the shadows of to-day we can perceive inevitable and full victory over despotism and brutality, because the will of all peace-loving races to act vigorously, and with complete self denial, must succeed in the maintenance of freedom for the advancement of civilisation.

The stamping out of Prussian militarism, while the primary and vital duty of to day, is not our only responsibility to ourselves and posterity. More is required. The war, with its revelation of great influences at work, has taught us all lessons which must be assimilated and acted upon to the fullest extent. These lessons are ethical, political, and industrial. They are interdependent; each affects the other; and it is difficult to discuss one without involving the other. But, obviously, in this Institute we are more concerned with the industrial and economic factors of the problems. Even with this limitation, the subject offers wide scope for consideration. The industrial lessons involve science and technics, design and manufacture, volume and economy of production, and, finally, the relation of both employer and employee to all of these. All are correlated, and we can only achieve our aim if everyone, from the least skilled of workers to the greatest of industrialists, resolves to consider the bearing of each not only upon himself, but upon the prosperity of the Empire.

Science comes first. It is the dominant factor, because it should be the beginning of all things, and yet it is only one element in the problem, because there must be co-operation between laboratory research and manufacturing development. This should be strongly enforced, as there is a tendency at the moment to neglect the other factors. There is a great need for the extension of research and experiment, and my experience is that much of this work is highly remunerative, either positively in improved processes of manufacture, or negatively in eliminating faults and obviating wastage. Much of it, however, is unremunerative, and in any case all of it requires money. Excessive competition in manufactures narrows profits, and leaves little money for such work. Manufacturing firms have therefore difficulty in finding the wherewithal to embark initially on scientific research work, or they are compelled, after starting it, to limit expenditure on its continuance. The refusal of workers to utilise to the best advantage improved methods of manufacture, evolved by experimental research, discourages industrialists in their evolution and application. These are axioms whose truth could be established by many examples. When a charge of lack of enterprise is made against manufacturers, blame should at the same time be laid at the door of workers who do not realise that their interests are intimately affected by the attitude they display in all such cases. There lies the political connection with the problem. It is not enough for the State to assist or otherwise encourage scientific research and experiment. The nation is equally concerned with the profitable application of the results, in order that national prosperity shall be augmented by ensuring that the fullest utility will be derived from scientific research and experiment. The question therefore is a national one. The employment of the people and their well-being depends upon plenty of work. This in turn requires the maintenance of a great export trade. Efficiency and economy in manufactures can do much to win and retain foreign as well as British Imperial markets. This necessitates advance towards perfection of design and greater volume of output, through improvement in the mechanical means of production evolved by experiment. It follows that research should be a charge on the selling price. To counterbalance this charge it is essential that the volume of output should be increased. Thus, when we reach the bedrock of industrial conditions we find that, unless restrictions and limitations dictated by workers' organisations are abolished, much of the gain possible to the nation due to research and experiment must be lost.

An example may here be given of the influence of the restrictive methods of Trade Unions. Early in the war it was found at the Parkhead Forge that the output from the respective machines was not so great as what the machines were designed for, and one of the workers was induced to do his best to obtain the most out of a machine. He very greatly increased his output, notwithstanding his predilection for trade-union restrictions. When it was found that the demands of the Government for a greatly accelerated production of shells required the employment of girls in the projectile factory owing to the scarcity of skilled workers, these girls in all cases produced more than double that by thoroughly trained mechanics—members of the trade unions—working the same machines under the same conditions. Three representative cases may be quoted thus: In the turning of the shell body the actual output by girls with the same machines and working under exactly the same conditions and for equal number of hours was quite double that by trained mechanics. In the boring of shells the output was also quite double, and in the curving, waving and finishing of shell bases quite 120 per cent. more than that of experienced mechanics. These conditions applied to war time when the peril of the nation demanded unselfish, patriotic exertion by everyone, and the men who thus limited the output can only be regarded as unworthy of the privileges of citizenship. In peace time the same results, due to restrictive measures, must necessarily handicap severely all manufacturers in their aim to advance the prosperity of the nation by ensuring adequate employment for all.

There is little need to demonstrate that ideal conditions in manufacture are associated with a higher rate of wage and large total earnings per worker per week, and this is attainable without forfeiture of a satisfactory profit, provided—and this is the crux of the whole problem—all workers make the most of all the appliances which scientific research and mechanical experiment may place in their hands, by increasing the volume of production per unit of time and by working full time. These, again, are well-known economic laws, but they are not enforced often enough. Until they are applied, the gain from the application of science to industry will not be fully realised for the benefit of the workers of the nation.

The awakening of the worker to such responsibility is thus as important as the arousing of the nation to the need for more scientific methods. But that does not in any way excuse the manufacturer for any deficiency in enterprise. In fairness, however, it should be made clear that some progress has been made in this direction in our own industry. A few iron and steel manufacturers as long ago as the 'eighties began tentatively to carry on chemical and metallurgical research work, and they have been steadily and continuously increasing the extent of the work done, with very satisfactory results. The present crisis and the prospect of a great trade war in the near future justify a consideration of the importance of increased diligence in this essential department of industrial activity and of the encouragement afforded by results in the past.

Scientific research falls naturally into two main divisions, and in considering how such work can be extended it is important at once to differentiate between the two. The work may be characterised in the one case as purely theoretical, almost classical; in the other as distinctly technical or practical. In the one, the results are indicative of potentialities for the future, more or less remote; in the other they are for immediate application, or generally contemporaneous with actual manufacture. Obviously only a limited amount of what I have termed classical research can be undertaken by the manufacturer, particularly where the current demands for chemical, metallurgical, or mechanical research for practical work monopolise much time and apparatus. Such classical work must therefore be separately undertaken. Where it is not dependent upon experience in every-day industrial work, it would seem that State or other public laboratories could readily undertake it. This condition would apply to new processes, to new discoveries, or to new materials. This line of demarcation of scientific work is further justified, because in public laboratories the difficulty of practical direction or control is often experienced. Where there is an attempt to do work capable of immediate application, it becomes essential that the guiding influence should be immediately conversant with every-day practice in the factory. In this category there are therefore included improvements, whether in chemical or mechanical processes, in combinations of metals, or in the reduction of the cost of production. All of these are more or less dependent on precedent, and consequently require complete intimacy with existing conditions.

There should be no disposition to limit the original or purely classical work in scientific research. When this is borne in mind only good can accrue from close association, even in such purely scientific research, between the industrial and the theoretical scientist. What is distinctly theoretical to-day may become the practice of to-morrow, and no one who has been associated with such work can fail to realise that there are no more difficult questions presented for decision than the potentialities, from a commercial point of view, of problems solvable in the laboratory. There are many instances of this. When Kelvin and Joule showed theoretically in the 'fifties that a compressed gas upon issuing from a nozzle would be lowered in temperature, and when they proved their deduction by experiment shortly afterwards, no one, probably not even those distinguished physicists themselves, recognised the immense commercial possibilities of these purely scientific discoveries. It was not until forty years later that Hampson utilised the experiment in a machine in which, by expansion, the temperature of a gas was reduced, cooling, in turn, gas which had not been expanded, and thus, by progressive stages, lowering the temperature until the gas became liquefied. This first successful liquid-air machine was further improved by Linde. The contemporaneous researches of Claude on the separation of oxygen and nitrogen from liquid air resulted in the production, on a profitable basis, of pure oxygen and nitrogen from the air, and now there are installations thus dealing with 100 tons of liquid air per day, separating the constituents into commercially applicable commodities. From this we have the pure oxygen for cutting iron and steel, including armour-plate, by the oxy-acetylene process, thereby cheapening many engineering productions. By the aid, too, of the oxy-hydrogen flame pure alumina has been fused, and the manufacture of artificial emeralds and rubies may become a profitable industry. Many examples of the advantages of new applications of oxygen can be found in the *Journal* of this Institute, such as the increased efficiency of blast-furnaces when pure oxygen has been added to enrich the blast.

With the nitrogen got from liquefied air it has been found possible to produce nitrates, &c., for agricultural fertilisers, and to-day, through the application of theoretical principles involved in chemical reactions, thousands of tons of artificial nitrate are produced with great advantage to agriculture. Moreover, the cyanamide produced by the application of nitrogen to calcium carbide, when treated under pressure with water, gives off ammonia, which can be converted into nitric acid, one of the most important constituents of our explosive compounds. In the laboratory, too, creatin has been produced from cyanamide, and it is within the range of possibility that food material may yet be manufactured direct from the atmosphere by inorganic means.

Purely theoretical research may thus yield important commercial results, and we are thus brought into contact with one of the difficult problems associated with national expenditure on such work. It is admitted that science knows no boundaries; but at the same time there is the important commercial rule that national expenditure must be justified by national gain. Where humanitarian work is involved no one will object to the gain from national expenditure being universal. Thus, all work for the prevention of accidents in mines, or in other employments, may be undertaken by the State, and the publication of results broadcast be justified. But where a new discovery, a new process, or new materials of great advantage to the industry of a nation are evolved, the advantage ought to accrue to that nation. It is admitted that between the discovery of the germ of a great idea and its application to manufactures much diligent work must be done, and that, too, of an important scientific character. But with the disclosure of the basic idea the subsequent work becomes inviting, perhaps comparatively easy, even if it is expensive or requires long and expert experiment. With the conduct of research in public laboratories a difficulty arises in connection with the publication of scientific results. They may be purely theoretical or classical, as was the discovery of Kelvin and Joule already referred to; or they may suggest a goal to be reached by a fairly well-defined line of attack in research. This was the case in connection with the much-discussed production

* Delivered at the Iron and Steel Institute, May 4, 1916.

of synthetic aniline dyes. Through lack of enterprise on the part of the British chemists, the Germans were induced to take up the germ idea. It is difficult, if not impossible, to state either the amount of time or of money spent on scientific research by the Germans for the development of this one branch of industry. It took 17 years to develop commercial manufacture from laboratory production of indigo, and it is understood that 1,000,000*l.* were spent on research on this one dye alone. Two chemical companies bought up Baeyer's original patent and pooled their resources, working together to develop the process. After 16 years they had come to the conclusion that it was not possible commercially to apply the process and dissolved their partnership. It is an interesting example of German methods that within a few weeks after this one of the companies announced that they had solved the problem, and for four or five years they were in sole possession of the artificial indigo market until a rival process was discovered.

During the progress of these experiments no information whatever was divulged. It is at least doubtful if such secrecy could be realised with corresponding work in our public laboratories. There should, however, be a great extension of the practice of conducting experiments on behalf of firms who direct and pay for such research, particularly of firms who desire to follow a definite line of research not immediately connected with any of their manufacturing processes, and whose current work does not permit of such researches being undertaken. No doubt in the future there will be much of this work for such public institutions and a satisfactory measure of secrecy will be attained. There would no longer be the objection that the fullest experience of current works practice is not available by those engaged in the public laboratory, if there were such direct and close contact between the public laboratory and the works of the firm directing and paying for the research. The chemist or experimenter from the public laboratory might even personally undertake, in association with the works staff, some of his research on a manufacturing scale at the works.

Another useful work which might be extended in public laboratories is the training of chemists suitable for works laboratories. One of the difficulties in finding a scientific staff for the factory is the limitations of our educational system. It has been put on record recently that at Cambridge only four colleges are presided over by men of scientific training, at Oxford not one; and that of the 35 largest and best-known public schools 34 have classical men as headmasters, and in no case do scientists hold a high place. It may be contended that such institutions were intended originally to give a classical or liberal education; that they were based on the concept that the fundamental principle of education is the cultivation of the mental faculty. On the other hand, science has become so essential, not only to the industrial but even to the domestic life of the nation, that scientific training might be made to serve a greater part in the future than in the past in cultivating the mental faculty. In any case the accepted principle that entrance to the largest number of posts in the Civil Service should be contingent on an examination where science plays the smallest, if not a negligible, part, tends to encourage the youth of the country to neglect scientific training and to bring into the service of State departments, many of which are concerned with scientific work, men with little knowledge of and less sympathy with science. Indeed, as almost every Government department is necessarily connected more or less with scientific problems, it would be to the benefit of the State if many of those appointed to the Civil Service were masters of science. The State endowment of research has been delayed, and is now hampered, by the absence of this influence in Government staffs. We are a scientific nation; if not, we ought to be. And yet no single scientist *per se* has ever been entrusted with the absolute control as a Cabinet Minister of any department of State, however intimately it is concerned with the training of science, the conduct of scientific research, or the application of the results of such work. Until there is an educated and liberal-minded control of our industrial and commercial Government departments, the true relation of the State to science can never be realised nor its benefits fully materialised.

It is because of the gradual awakening of publicists to these considerations that many look with the greatest measure of hope to a quickening of interest in scientific research within factories. No firm which neglects such work can expect to achieve the highest success, industrially or financially. We must still pursue a vigorous policy of enlightening the working classes on the importance of the fullest advantage being taken of all chemical and mechanical improvements conducive to increased production. But at the same time no opportunity should be neglected of enforcing the need for a more active participation in research and experiment by manufacturers in all processes of production. Great responsibility rests upon the members of this Institute as iron and steel manufacturers. We supply a preponderating proportion of the material for all manufactures, and thus any advance we may make either as regards quality or the cost of such materials must have influence on the total volume of national output and on our ability to command the markets of the world. I can almost hear now an echo of the word "Stahlwerksverband," but that opens up a phase of the subject with which we are not here immediately concerned. Certainly much may be done by ourselves to check the ruinous competition amongst ourselves and from foreign sources by "dumping" processes as well as by the awakening of the working classes to their part of the responsibility for improving trade. That, however does not relieve us of our duty to the State in this matter of scientific advancement.

Moreover, I am persuaded, from my own experience, that reward follows from the pursuit of scientific methods. Only a year ago Sir Robert Hadfield told us that research regarding the production of sound ingots for projectiles reduced the number of wasters from 6.2 per cent. to 1.4 per cent. This is only one department of our operations. In every process a certain number of failures or wasters is bound to occur. The general standard, too, can be improved. Continuous investigation by a trained staff is thus absolutely necessary for efficient work, and it is essential that managers and works superintendents should be sufficiently acquainted with the scientific side of their work to apply in a practical way the recommendations made from the laboratory and ensure the desired results. This presupposes co-ordination between the manufacturing staff and the research staff, so that we have here again a proof that scientific work must be done in the works, under the stimulus of the chief. For this reason, too, it is desirable that young men should have at least the first part of their practical laboratory training within the works. Educational authorities should maintain a closer contact with the works, so that not only

would these young men be grounded in school laboratories for practical work, but the student would have a better chance of being placed subsequently in a position in the works laboratories, where his ability would more readily be developed. And here I cannot refrain from the suggestion that the training in works laboratories should be regarded as part of the higher education of the future metallurgist, and that there should not be an immediate desire for high remuneration. Experience is of far greater permanent value than the earning of a big wage at the commencement of a scientific career.

When research is made in the factory there is a probability that the results will be more speedily applied commercially. The initial work which resulted in special alloys and in the heat treatment of steel was undertaken in the laboratories of the universities and technical institutions; but when works laboratories took up these subjects their great practical significance was more quickly established. The same applies to the study of the molecular structure of metals, and its influence on the soundness and tensile qualities of metals. Quite fifty years ago, Sorby, when developing the subject of the petrography of rocks, applied the microscope to the examination of the polished surfaces of steel, and investigated the structure revealed when they were etched with different acids. This work was systematised by Osmond and when he, in 1890, read his paper before this Institute on the critical points of iron and steel, his proposals doubtless seemed to many too theoretical; and yet they have become common practice to-day. Nor can we forget the services of Roberts-Austen, Stead and Arnold in this connection. Now no steel-works can afford to be without a metallurgical microscope for the efficient control of high-class products, since it is specially valuable for the examination of failures. To know the cause of failure is to avoid its repetition. As a former President, Roberts-Austen, said, regarding allotropy of iron: "There is no other fact which so profoundly affects the industry of the world."

In this connection, too, one recalls the service which Le Chatelier rendered by his research on thermo-electricity, and his discovery of the platinum-rhodium pyrometer. It placed at once in the hands of the technologists a simple and accurate method of measuring temperatures with a delicacy of control which they have greatly applied and appreciated. Thus may the results of one science be utilised by another. It establishes also the view that while we should be masters in one branch of science we should know a little of all others, and watch all progress sympathetically and intelligently.

As proof alike that we are not negligent in research and that good results may accrue, one or two other examples of such work may be referred to. Great gain has resulted from systematic study of alloy steels. A beginning in this department of work was made nearly thirty years ago by Hadfield in his researches with manganese steel, by Holtzer with chrome steel, and by Riley with nickel steel. It was about this time that naval artillery, using high-grade forged-steel projectiles, hardened by a special process, compelled the armour-plate makers to tackle the problem of the composition of steel plates, in order to achieve the highest resisting power and to reduce weight. My early experiences impressed me with the limitations in the proportions of nickel and carbon above which one could not go at that time without encountering difficulties. Now it is pleasant to look back upon the unceasing research work carried out at Parkhead and other works to solve this problem, resulting in armour of comparatively light weight to resist the attack of guns of great power, particularly in modern high-speed scout-cruisers. To-day it is not permissible to deal with the latest developments in this direction, but before the war I took occasion, at the launch of H.M.S. Inconstant, to refer to this subject, and it may be permissible to quote what was then put on record—that, although the weight of the armour per square foot was only about one-quarter that of twenty years before, it had greater resisting power. Similarly, the guns had five times the muzzle energy of those of the same calibre available twenty years before. The improvement in projectiles gave still greater penetrative power. For each ton of machinery it was possible to get four times the horse-power for driving the ship. And in the structure of the ship the improvement in respect of weight per unit of tensile strength was still greater. Iron and steel manufacturers are entitled to claim credit, along with the chemist and the thermodynamist, in these marked improvements which enable light scout-cruisers to have those superior fighting qualities that were demonstrated during our naval victories in the North Sea.

Another and an entirely different example may be quoted. In 1889 Sir Robert Hadfield dealt before this Institute with alloys of silicon and iron, and his investigations, taken up by others, led to the important discovery that certain elements, like silicon and aluminium, could render steel more permeable under low magnetic fields than the purest commercial iron then available. The usefulness of this discovery to the electrical engineering trade was at once recognised, and a special silicon steel was shortly afterwards applied to the manufacture of transformers. From this purely scientific work there has sprung the trade in special transformer sheets, &c., and it has been computed that in the nine years from the introduction of this material the aggregate output in America alone of machines using it amounted to no less than 14,000,000 kilowatts, and the annual saving in the latter year in electrical energy, due to its better magnetic properties, was about 10,000,000 dollars.

A further illustration of the value of organised research applied to the improvement of an industrial product is afforded by that undertaken to find the factors which prevented the present metallic filament lamp from being run at a higher efficiency than 1 watt per candle-power. Ordinary tungsten lamps can be run at a higher temperature with greater efficiency, but they deteriorate rapidly, owing to the breaking of the filament or the blackening of the bulb. Long experience has shown that with carbon lamps a high vacuum was essential, but Langmuir, who carried out this work, found with tungsten lamps that a very much better vacuum than was usual did not improve the life of the lamps—the blackening of the bulbs being the most important cause of the failure. Painstaking work eventually traced the blackening to the vaporisation of the metallic filament itself. This could only be avoided by increasing the pressure of the gas in the bulb, and hydrogen and nitrogen at atmospheric pressure were tried, and the latter proved fairly successful. To ascertain the condition of greatest efficiency a long series of experiments were made with wires of different diameter and length, and the laws connecting these with the radiating power were worked out very completely. By adopting the results arrived at, a lamp was made which had an efficiency of 0.5 watt per candle-power and an average life of 2000 hours—the now well-known "half-watt lamp." This it is safe to predict will ultimately supersede all other forms of glow lamp, and be a serious rival even to the flame arc itself.

One of the most striking adaptations of laboratory methods to works conditions is seen in the Haber process for manufacturing ammonium sulphate carried out by one works on the Continent. In this, pure nitrogen

obtained from liquid air is directly combined with hydrogen under the influence of a catalyser, for which purpose metallic osmium or uranium seems to be best suited. Special reaction vessels are used, heated to 550 deg. Cent., and the gases unite under a pressure of 175 atmospheres, forming about 8 per cent. of ammonia, which is removed by liquefaction. It is reported that 120,000 tons of ammonium sulphate were produced by this method in 1914, and extensions in progress would enable 300,000 tons per annum to be made. As the world's production of ammonium sulphate in 1914 was 1,365,700 tons, the importance of this scientific development to by-product recovery plants is obvious.

As an example of the benefit of perhaps more everyday scientific work, may I give you some data to show the difference between scientific control of processes by quantitative measurement and the exercise of judgment by the individual based only on experience. The work in this instance was carried on in connection with the open-hearth process at the Parkhead Works by two members of the staff, Mr. Service and Mr. McCance, with a view to improving the quality and regularity of acid open-hearth steel. It was observed that a large proportion of flaws in the manufactured steel article could be traced to the presence of non-metallic impurities such as slag, sulphides, &c. The appearance of the fracture of a tensile test, as is known, is a fairly good guide to the quality of the steel, and it was found that an abnormal and irregular fracture was generally associated with such segregations of non-metallic material. A careful examination revealed the fact that although such segregates gave a strong sulphur reaction they were, in the majority of cases, really mixtures of manganese and iron silicates containing sulphur (probably as manganese sulphide) in solution. The presence of alumina also in their composition pointed to the melting furnace as the source from which they came, and an investigation of the process of manufacture was undertaken in an endeavour to trace any connection between the furnace conditions and the presence or absence of these impurities. At the outset it was found, as could be expected, that a low temperature of casting favoured the retention of these impurities in the steel. By means of an optical pyrometer continuous records were then taken of the temperature of a melting-furnace from the beginning to the end of its operation, as well as of the casting temperature of the steel. After the first difficulties had been surmounted, it was found that the pyrometer gave a valuable indication of the temperature working of the charge. It was then used as a means of control, and as such has given very satisfactory results, ensuring a regular and uniform heat for all charges. Attention was next directed to the bearing which the composition of the slag might have on the quality of the steel, and here again it was proved that a more or less definite relation held. Without entering into details, it may be briefly stated that the ratio of the percentage of silica to iron (existing as ferrous oxide) in the slag during the boiling period was the important criterion. For a good quality steel this ratio should not exceed 1.8 to 1.9 per cent. during the boil, and for the finishing slag it should not be less than 2.5 per cent. The methods which have been devised to meet these new conditions have enabled us to make steel of the best quality from a charge containing 75 per cent. and more of scrap, and they have been in practice at the Parkhead Steel Works for over two years in the manufacture of armour-plates and special steels, while the results have fairly justified their adoption. The illustration on the opposite page is from a print of an ingot made under the conditions stated to show the great freedom from segregation.

Thus, whatever the State may do on a national basis, as I stated at the outset, close co-operation is essential between theoretical and practical scientists to ensure that even what I have called "classical work" may find ready absorption in the factory. There is still great need and great scope for research work in all factories. In the metallurgical industry we have gone some way along the road, but there must be fuller recognition of the benefits which can be realised. The engineer is calling for metals of still higher quality and for a great range of purposes. The thermodynamist is demanding iron and steel to resist higher pressures and temperatures. Everyone is clamouring for reduction in cost, even in association with such high qualities. Scientific methods applied in the works can achieve much also in avoiding wastage, in ensuring greater reliability in processes, in providing labour-economising mechanical appliances, and by recovering all by-products. In the chemical and physical laboratories all of these contributories to high efficiency can be advanced under progressive management. Every industrial process should be examined constantly and methodically by the trained scientific staff, whose sole duty it would be to elucidate the principles upon which the process depends, and to ascertain, in the laboratory first, and afterwards in the works, the conditions of maximum efficiency. Every failure and every flaw should be recorded and explained, so that the cause may be avoided and the process of manufacture improved. Responsibility therefore rests upon all manufacturers to make such research work part of their productive methods. It is also necessary that managers of technical processes should be acquainted with scientific methods and contemporary scientific research, as upon them falls the duty of applying the results on an industrial scale.

As an Institute we have always encouraged science; let us, as individuals, strive to ensure that in the future our efforts will greatly exceed those of the past. But if such work is to be completely effective from the national point of view, not only in metal works but in all factories, a great duty and responsibility rests also upon the State and upon the worker. Instead of being hampered by legislation, manufacturers should be encouraged, because on manufactures the prosperity of the nation will depend much more in the immediate future than in the past. What is required is that everyone, scientist, technologist, employer and worker, shall do his best for the common weal. If time permitted it would be easy to demonstrate that many developments towards improvement and increase in production, in a great variety of factories, have been regarded as mediums only for justifying the same wage earnings for the same output with less physical effort. Were the highest efficiency of all such improvements realised by the workers, their earnings would be higher and the output would be greater without any increase in physical effort. Charges would be spread over the greater volume of output, manufacturers would be encouraged to prosecute research work to a still greater extent, and by the improving of the character of the production and the cheapening of its price the nation would be better equipped to face the keen competition in all the markets of the world which is bound to arise in the immediate future. There would be no unemployment problem. Thus, while we think of metallurgical science, we must not neglect the equally important subject of industrial economics and the duty of the State and the worker towards such problems.

THE ASPHALT INDUSTRY IN ITALY.—We read in the *Rassegna dei Lavori Pubblici e delle Strade Ferrate* that, apart from a few beds in Savoy, Switzerland, and Alsace, the most important deposits of asphalt are in Italy, in the province of Chieti, in the Abruzzi, and in Sicily. The Sicilian asphalt is richer in bitumen than that of the Italian mainland. The suitable percentage of bitumen for the Cairo streets is 6 per cent., and for the streets in Milan 9 per cent. Asphalt with 9 per cent. bitumen has so far been found satisfactory in the Palermo streets. The companies which work the Italian asphalt beds are not all German, as some Italian journals have stated; the most important, the Neuchatel Asphalt Company, Limited, the headquarters of which is at Scafa (Chieti), is a British company, having a capital of over 15,000,000 lire (600,000*l.*).

METAL-TESTING BY X RAYS.—The Transactions of the American Electrochemical Society, vol. xxviii., pages 407 to 418, contain some notes by Mr. Wheeler P. Davey on "Radiography of Metals," describing further experiments made in the research laboratory of the General Electric Company, of Schenectady. The radiograph of a steel casting, 2½ in. thick, taken with a Coolidge tube, showed an irregular white band, and when drilled the presence of a blow-hole was revealed. Experiments were then made with ¼-in. plates, partly drilled through with small holes or grooved and piled upon one another, and in this way it was found that an air-inclusion of 0.021 in. thickness could be detected in 1½ in. of steel, and an air-inclusion of 0.007 in. in ¾ in. of steel. The spark-gap in these last experiments was 15 in.; in others, shorter gaps were used, the increased spark-gap giving some slight advantage. It had been feared that scattering of the rays would make the radiographs less distinct at greater spark-lengths; but this proved not to be the case. It was further observed that autogenous steel welds (¼-in. plates) could be examined in this way. A merely superficial weld was easily recognised; oxidation of the surface and insufficient heating were also detected, while a perfect weld gave a uniform radiograph. Fluorescent screens are not sensitive enough for this work; it is best to take radiographs of specimens having machined surfaces.

AMERICAN METALLURGY.—The programme of new construction and improvements prepared by the United States Steel Corporation largely aims at the economising of working expenses through the installation of the latest and most modern type of facilities, including the conservation of by-products and diversifying lines of finished products. At Clairton, Pennsylvania, it is proposed to establish 200 ovens; at Youngstown, Ohio, 210 ovens; at Cleveland, 180 ovens; and at Lorain, Ohio, 225 ovens. At the Edgar Thomson works the improvements contemplated comprise a new central pumping-station and a water-distributing system; at Schoen Steel-Wheel Works an additional unit, increasing the capacity by 150,000 wheels per annum; at Clairton Works two additional open-hearth furnaces, and a 1200-ton metal-mixer; and at the Donora Works a new duplexing steel plant, comprising two 25-ton converters and a 1300-ton mixer. At the Ohio Works, Youngstown, three additional open-hearth furnaces are to be provided; at McDonald, near Youngstown, a new merchant-bar plant, to comprise three bar-mills, six hoop-mills, and one band-mill with auxiliary departments, and at Ellwood, Pennsylvania, the Shelby Steel-Tube Company will construct a large extension to its Standard works. At the Gary works of the Indiana Steel Company four additional blast-furnaces, a duplexing steel plant, comprising two 25-ton converters, and two 100-ton tilting open-hearth furnaces, a 40-in. blooming-mill, a 160-in. sheared-plate mill, two 10-in. and one 20-in. merchant-bar mills, a forged-steel wheel plant, four 3000-kw. electric gas-engine units, additional waste-heat boilers at open-hearth plants, and two 7500-kw. steam turbo-electric units are in contemplation. At the works of the American Sheet and Tin-Plate Company at Gary, a new tin-plate plant, comprising 24 hot-mills, with an annual capacity of 2,250,000 base-boxes, are to be provided. The total cost of these and other important improvements is estimated at 70,000,000 dols. The amount unexpended on authorised appropriations for extensions, additions and improvements at the commencement of March, 1916, was 91,200,000 dols., and it is estimated that not more than 75,000,000 dols. of the total will be paid out in 1916.

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall Street, E.C.

Australia: The Melbourne office of His Majesty's Trade Commissioner in Australia reports a call for tenders by the Commissioner, Queensland Government Railways, Brisbane, for the supply of superstructures for steel bridges. Sealed tenders, on the proper forms, will be received, up to noon, on May 16, at the office of the Agent General for Queensland, 409, West Strand, London, W.C.

South Africa: With reference to the revised scheme for supplying the Witwatersrand with water from the Vaal River, it is notified that the *South African Mining Journal*, Johannesburg, publishes further particulars on the subject, as follows: The whole of the preliminary arrangements in connection with the commencement of the scheme were made in July, 1914, but the outbreak of war made it quite impossible for the Rand Water Board to raise a loan on reasonable terms. It has now been found practicable, however, to borrow from the Board's redemption fund sufficient money to carry out a modified Vaal River scheme which would provide such a supply of water as would be likely to secure the Board's consumers against a shortage for some years to come. This modified scheme provides for the erection at Lindeque of a barrage composed of 36 gates, each 25 ft. high and 30 ft. wide. It will impound altogether 13,633 million gallons, of which the Board will be at liberty to abstract annually up to 7300 million gallons, or 20 million gallons a day. The estimated cost of the whole scheme is 758,000*l.*, of which 42,000*l.* has already been spent on the collection of data, the erection of weirs and other minor works and services classified under the head of preliminary expenses. The chief engineer states that the whole scheme can be completed and water from it brought into service in three years from the date on which construction work is actually commenced.

Straits Settlements: According to the *Straits Settlements Gazette*, sealed tenders will be received at the office of the Colonial Engineer, Public Works Department, Singapore, up to August 14, for the construction of a steel bridge comprising a centre span of 215 ft. and two side spans of 110 ft. 9 in., over the Muda River, Province Wellesley.

Brazil: The *Diario Official*, Rio de Janeiro, publishes a Decree (No. 11,992) approving the definitive plans for the construction of an extension of the Theresopolis Railway between the station of Theresopolis and that of Varzea, a distance of 3937 m. (about 2½ miles). The estimated cost of the undertaking is 596,000 milreis (about 29,800*l.* at current rate of exchange).

The *Diario* also contains a Decree (No. 11,994) approving the project presented by the Companhia Paulista de Estradas de Ferro for the extension of the Rio Claro-Itirapina line as far as S. Carlos, at an estimated cost of 1,632,773 milreis (about 81,600*l.* at current rate of exchange) and also authorising the same company to proceed with surveys for the further extension of the same line to Araraquara and also a line from Itirapina to Jahu.

SOME EFFECTS OF THE BULKHEAD COMMITTEE'S REPORTS IN PRACTICE.*

By A. T. WALL, A.R.C.Sc., Associate Member.

(*Continued from page* 402.)

PART II.—SUNDRY MATTERS IN THE APPLICATION OF THE RULES.

THERE are quite a number of matters in the application of the rules which will repay consideration, and it is thought that they are of sufficient interest to merit the attention of members of this Institution.

Method of Working with the New Rules.—The initial work to be carried out before the floodable lengths can be lifted is quite appreciable. The volume of the whole of the spaces in the ship has to be ascertained in order to decide the mean permeability as well as the end permeabilities. It is perhaps a little unfortunate that the criterion of service should be based on the gross tonnage spaces of the ship. A good deal of work is involved in working up the gross tonnage, and the method does not make for simplicity. If variations from the standard form are to be considered in the design stages, it is necessary to go fully into the lines of the ship, a course which was not always necessary before the introduction of the rules. It would, of course, be done if the ship estimated for became an actual contract. Having determined the lines, all the hydrostatic particulars have to be worked up, including the sectional area co-efficients and the floodable lengths lifted from the curves. All this takes considerable time, and adds very appreciably to the work of the designer. Part of this work must be done before the general arrangement and estimate for this ship are started, and when these are completed, it may be found necessary—in fact, generally will be found necessary—to alter the form of the ship, which modifies all the work which has been done previously in deducing the original floodable length curve. This is all the more confusing, as in the early design stages all the details may not be definitely

* Paper read at the Institution of Naval Architects, April 13, 1916.

settled, and alterations afterwards may cause modifications in the bulkhead spacing or the draught. Cases may also arise where modifications may be desired to the superstructure during building, or even after completion. This will influence the factor of subdivision, and may cause a compartment or compartments to fall outside the limiting length, thereby penalising the draught of the ship.

Permeability of Ends.—The permissible length of compartments at the forward and after ends of a ship is materially influenced by the mean permeabilities of the ends, and the smaller these can be made the greater will be the permissible length. With a ship which is required to carry a certain total number of passengers it can be easily shown—although the arrangement may not always be a practical one—that it will always increase the permissible length of compartment if all of them are carried above the bulkhead deck, since the end permeabilities will then have minimum values; and, further, the mean permeability of the whole ship will be smaller than if some of them were carried below the bulkhead deck, and in consequence the factor of subdivision will be greater.* This, of course, does not apply to vessels whose mean permeability is always above 80 per cent.; that is, to steamers carrying a large number of passengers. With all spaces below the bulkhead deck free from passengers, a greater cargo capacity is available, and with the same arrangement of bulkheads a deeper draught can be given to the ship, thus increasing the dead-weight capacity as it should be.

Criterion of Service.—The criterion of service, although intended to take account of the number of passengers carried, will not always form a correct measure of that number. The actual number of passengers in any space will depend on their class. An illustration of this recently came under notice with two otherwise somewhat similar ships. In one case third-class passengers were carried and in the other emigrants. With the third-class accommodation 1250 passengers were carried in certain spaces, whereas, if this had been arranged for emigrants, 1900 could have been taken—a difference of over 50 per cent.

Alternative Passenger and Cargo Spaces.—In all ships where spaces are arranged, by the provision of the necessary sidelights, ventilators, &c., so that passengers or cargo may be carried alternatively, it will usually be advisable to assess these spaces at 95 per cent. permeability, and space the bulkheads accordingly. The ship would suffer in draught when these spaces were used for passengers, and a new survey would be required to fix the new load-line. This does not apply to 'tween decks, which may be used alternatively for passengers or cargo when two load-lines are allowable.

Small Ships and Mean Permeability.—The special factors of subdivision given by the Committee for ships under 295 ft. in length show an interesting feature. For a ship between 295 ft. and 259 ft. in length, her mean permeability will decide whether she has to be subdivided throughout the whole length or only for 35 per cent. of the length forward. For example, if her length is 270 ft. and her mean permeability proves to be less than 76.94, the latter subdivision only is necessary, but if the permeability is greater than this she would have to be subdivided throughout. This is illustrated in Case 5, given in the first part of the paper. Under such circumstances it may be worth while to dispose of the passengers, so that the mean permeability is less than the 76.94 mentioned.

An Anomaly.—A subdivision anomaly will occur in many ships when the factor of subdivision is round about 0.5. The case was brought to notice in dealing with a vessel 530 ft. in length, in which the mean permeability gave a factor of subdivision just under 0.5. The vessel was a low-powered one, and in consequence the engine and boiler rooms were comparatively short. Under the full rules, by using the principle enunciated in paragraph 36 of the Bulkhead Report, whereby the length of two adjacent compartments may be equal to twice the permissible length of compartment, it was found that the holds adjacent to the machinery space could be made much greater then the permissible length.

In consequence a greater draught could be obtained in the ship, with the same number of bulkheads, than if each compartment did not exceed the permissible length. Fig. 10 (above) illustrates this case. When the mean permeability is 76.58, giving a factor of subdivision of 0.5, the draught could be 30 ft. 0½ in., the dotted curves in the figure indicating twice the permissible length of compartment; whereas, if the factor of subdivision was 0.501, according to the strict rules, the draught could only be 29 ft. 3 in.; that is to say, although in the second case the vessel has a lower mean permeability, the draught must be less. To bring the draught in the second case down to that in the first, the factor of subdivision would have to be 0.533, requiring a mean permeability of 74.29 per cent.

Freeboard and Sheer in New Ships.—Actual values of freeboard ratios for existing ships were examined, and while it was found that these did not go above 0.65—unless in exceptional cases—they often had values as low as 0.10. The spacing of bulkheads required by the Committee's Reports in vessels whose freeboard ratios were low, say, from 0.10 to 0.25, was considered. It was found in practically every case that such low values could not remain in use if anything like a practicable arrangement of bulkheads was required in the ship. The shelter-deck, well-deck, and three-island vessels are the only ones in which really small freeboard ratios are permissible under the Load-Line Tables; and, as has already been shown, suitable modifications must be brought about in these ships if the bulkheads are to be spaced in accordance with the requirements of the Committee. It was thought that the freeboard ratios of ships built under the New Rules could not reasonably be below 0.20, and generally would not be less than 0.25, and that the very small freeboard ratios which have been common in certain ships will be increased in the future.

Increase of sheer not only helps the floodable length *per se*, but to a minor extent, by decreasing the end permeabilities of the ship, since it generally adds volume to the cargo holds. Large sheer ratios will therefore probably be adopted in future ships.

Stability.—The items mentioned earlier (pages 399 and 400 *ante*), when added to the ship, invariably raise its centre of gravity. The necessary increase in beam was estimated for Case 5 in order to give the same metacentric height in the light condition in No. 2 ship, Fig. 7 (page 401 *ante*), as in No. 1 ship (Fig. 6, also on page 401 *ante*) The beam must be increased by 10 in.

Stability during flooding and in the flooding condition is too large a subject to deal with here. The question was treated in a paper on "Some Principles Underlying the Watertight Subdivision of Ships," read last year before the Liverpool Engineering Society by Professor T. B. Abell, and also in a paper on "The Time Element and Related Matters in some Ship Calculations," read in December last before the North-East Coast Institution, by Professor J. J. Welch.* In view of the number of ships that have capsized after receiving damage during the present war, it seems likely that more attention will be given to this matter in the future. The stability in the damaged condition is connected with the reserve of buoyancy after damage, not only in spaces below the bulkhead deck, but also in erections. There is, therefore, a connection between it and the factor of subdivision, influenced by the permeability.

Strength.—The load draught under the Bulkhead Rules will often be less than that permissible under the Freeboard Tables. The steel scantlings of the parts of the ship contributing to longitudinal strength are usually fixed by Registration Societies on the assumption that the load draught will be that obtainable under the Freeboard Tables. The question therefore arises whether, when the draught is less than this, some reduction might not be made in these scantlings. In the report of the Committee appointed to advise on the Load-Lines of merchant ships the standard of longitudinal strength is measured by the modulus of resistance of the midship section, which is expressed by a formula showing that it varies directly as the load draught. If the strength of vessels with a load draught less than that given under the Freeboard Tables could be reduced in this proportion, some appreciable saving in weight of steel could be effected. For example, in Case 2, given in Part I., the load draught to the "full" standard is 4 per cent. less than that permissible under the Freeboard Tables, and since the distances of the material from the neutral axis of the section are unaltered in this case, the area of the material could be reduced by this 4 per cent. This would mean a net saving in steel of approximately 110 tons.

Accuracy in Practice.—Although there is a large amount of extra work involved in design by the advent of the Bulkhead Committee's Rules, it is justified if by the greater accuracy obtained the safety of the ship can be increased. Nevertheless, it does seem doubtful if this great accuracy can really be obtained in practice. There are assumptions made by the Committee which are bound to be approximations; perhaps the greatest of these is the fixing of the permeabilities of various spaces. Large variations must occur in this value in practice, and an addition of only 5 per cent. to the permeability of the end of a ship, from, say, 65 to 70 per cent., is enough to cause a change of 7½ per cent. in the floodable length at the 70 per cent. station, representing about 12 in. in draught for a ship with a depth to the bulkhead deck of 40 ft., floating at a draught of 26 ft., and block coefficient 0.72.

In working up the floodable length curves, it is presumed that the vessels were assumed to be on even keel; that is, with the load water-line parallel to the tangent to the margin line at its lowest point, whereas in loading up they may easily have an appreciable trim, say, by the stern, when the subdivision of the after end may not fulfil the Committee's requirements.

There is one point in connection with the rules about which some misconception seems to have arisen. It is often taken for granted that a vessel with a factor of subdivision of 0.5 is necessarily a two-compartment ship. Actually, at and about midships the length of two adjacent compartments based on a factor of subdivision of 0.5 is really less than the floodable length, but at the ends two such compartments are always in excess of the floodable length, and therefore the ship cannot be described as a two-compartment one. This is shown in Fig. 11. These remarks do not apply if the combined length of each pair of adjacent compartments does not exceed the floodable length multiplied by twice the appropriate factor of subdivision. (See paragraph 36, Bulkhead Rules.) The same applies where a factor of subdivision of 0.333 is used; such a vessel will not necessarily be a three-compartment ship throughout the length

(To be continued.)

Fig. 10.

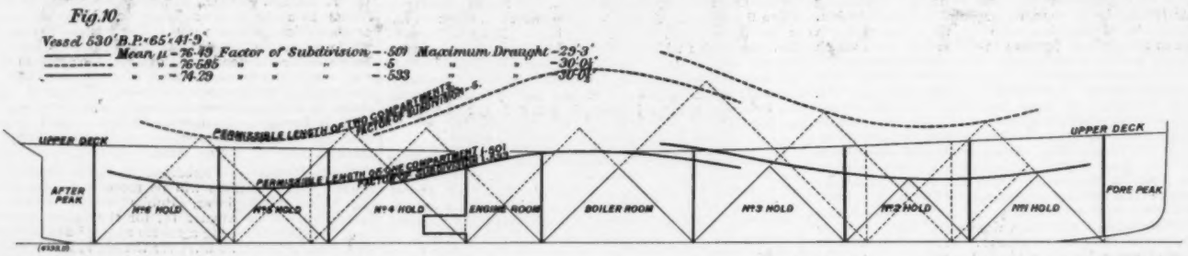
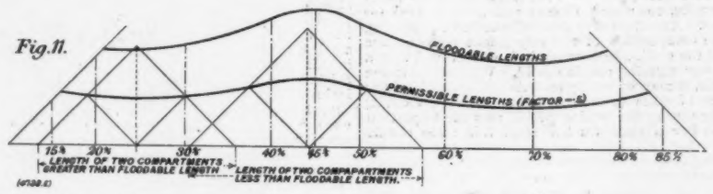

Vessel 530' B.P. × 65' × 41'9"
Mean μ = 76·49 Factor of Subdivision = ·509 Maximum Draught = 29'3"
" " = 76·685 " " " = ·5 " " = 30'0½"
" " = 74·29 " " " = ·533 " " = 30'0½"
PERMISSIBLE LENGTH OF TWO COMPARTMENTS FACTOR OF SUBDIVISION = ·5
PERMISSIBLE LENGTH OF ONE COMPARTMENT (·501 FACTOR OF SUBDIVISION)
UPPER DECK
UPPER DECK
AFTER PEAK
No 6 HOLD
No 5 HOLD
No 4 HOLD
ENGINE ROOM
BOILER ROOM
No 3 HOLD
No 2 HOLD
No 1 HOLD
FORE PEAK

Fig. 11.


FLOODABLE LENGTHS
PERMISSIBLE LENGTHS (FACTOR = ·5)
15% 20% 30% 40% 45% 50% 60% 70% 80% 85%
LENGTH OF TWO COMPARTMENTS GREATER THAN FLOODABLE LENGTH
LENGTH OF TWO COMPARTMENTS LESS THAN FLOODABLE LENGTH.

* This does not apply where permeabilities of ends must always be taken (by Rule) at 95 per cent., or, more generally, where end permeabilities exceed about 80 per cent.

* See ENGINEERING, vol. c., page 640.

SWEDISH COAL-MINING AT SPITZBERGEN.—The Swedish Company which controls the so-called coal deposits at Spitzbergen (the Isfjorden-Belsund Company) is about to start a working of the coalfields in question on a substantial scale at the Braganza mountains. The seams there are of considerable thickness and are almost horizontal. They are also located at a convenient height above the sea, and there are good conditions for the construction of quays in the deep Mijeus Bay. At the entrance to this bay lies an island which forms a natural breakwater, preventing the ice from penetrating into the bay, where consequently only winter ice has to be contended against, and owing to the influence of currents and tidal water this ice becomes loose early in the spring.

AMERICAN SHIPBUILDING.—Another shipbuilding plant is to be established on the banks of the Delaware, according to plans prepared by the Pennsylvania Shipbuilding Company, which has been recently organised for the purpose. The new plant starts with a contract for six 6000-ton tank steamers. The company has acquired land at Gloucester, New Jersey, with a frontage of 800 ft. on the river. Mr. H. Lysholm, superintendent of the hull department of the New York Shipbuilding Company, is to be general manager of the new concern. The six ships contracted for are being built upon Norwegian account. The American Shipbuilding Company has booked orders for three additional boats of the Welland Canal size for Atlantic coast trade. Two of these boats are to be built for the Mallory interests in New York. The American Shipbuilding Company has now 26 vessels under contract, to be delivered this year and in 1917; nine of these are for the Lake trade, and 17 are ocean vessels. The Pittsburg Steamship Company, a subsidiary of the United States Steel Corporation, has under contract six 12,000-ton ore vessels; three are to be delivered this year, and three in 1917. Four of the new vessels are to be built by the American Shipbuilding Company, and two by the Great Lakes Engineering Works.